ORIENTAL DRAINAGE.

ORIENTAL DRAINAGE

A GUIDE

TO THE COLLECTION, REMOVAL AND DISPOSAL

OF

SEWAGE IN EASTERN CITIES,

WITH A GLOSSARY OF SANITARY AND
ENGINEERING TERMS.

By

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A Text Book for Students of Oriental Sanitation.

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To

The late W. SANTO CRIMP, M. Inst. C.E.,
to whose friendly advice and encouragement
the writing of this book is largely due.

PREFACE.

The reception accorded to my two small books "Notes on Sewage Disposal" and "Further Notes on Sewage Disposal" has been so encouraging that I have been emboldened to carry out the wider project, long contemplated, of describing, among other kindred matters, the proved principles embodied in the Bombay Sewerage System; and in offering my work to the public my first and last wish is that it may prove useful, in however small a degree, towards furthering the progress of sanitation in tropical countries.

So long as Bombay remains the most cosmopolitan City in the East, so long must it present, as it certainly now does, an unrivalled variety of sanitary conditions. All the chief races of the world are represented, each with its own distinctive domestic customs and its own unalterable prejudices in sanitary matters, most of which the sanitarian must consider.

For these reasons I venture to think that within the narrow limits of Bombay alone there will be found instruction and guidance for the drainage of almost any tropical city. I hope, therefore, that the somewhat ambitious title which I have chosen for my work may not be deemed inappropriate.

In preparing "Oriental Drainage" my aim has been to lay down the general principles of drainage which experience has proved suitable for tropical conditions, rather than to describe the systems of different cities and remembering

that there is now a large section of the non-professional public in this country deeply interested in sanitary matters, I have endeavoured, as far as possible, to avoid technicalities, in the hope that what I have written may be easily understood by all. I fear many errors and omissions will be noticed, and for these I would crave indulgence; in a subsequent edition I look forward to either rectifying or supplying them.

I have dealt with Conservancy only where it is an integral part of Sanitary Engineering. Although its importance in all modern sanitary schemes cannot be overestimated, it is none the less separate and distinct from Drainage, and must always remain so. The two have so much in common and dovetail at so many points that for the good of a city it is essential that the Health and Drainage Officers should always co-operate in the closest and most harmonious manner.

Most of the analyses quoted in the book have been made by Dr. C. H. Cayley, M.A., M. D., D. Ph., and to him I am much indebted for all the trouble he has taken.

I desire also to express my thanks to many friends who have assisted me in the writing of this book. Among them to Mr. Nigel F. Paton; to my colleagues Messrs. N. Maughan and B. H. Hewett, A. M. I. C. E., M. I. M. E.; to Mr. F. W. Chanter, M. Inst. C. E., whose criticisms have been much appreciated, and lastly to my Assistant, Mr. Dinshaw D. Daruwalla, L. C. E., whose industry and ability in compiling information has been of the greatest help to me.

C. C. JAMES.

ERRATA.

Page 82, line 19, *add* "one of" after the words "It is."

Page 102, line 13, *add* "just described" after the words "water-carriage system."

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INTRODUCTION.

MANY standard books on Sewage Disposal and Drainage according to the practice in Western countries have been written, but so far no serious attempt has been made in regard to India although the want has long been felt by Sanitary Engineers. Many short works have been published on various subjects connected with the question, but none have dealt with it as a whole. The Author proposes in the following pages to endeavour to supply that want and to present the experiences obtained by him during his extended connection with the Bombay City Sewerage System. The necessity for a treatise on Oriental Drainage is emphasized by the fact that in dealing with the Sanitation of an Eastern City it has to be borne in mind that what may be wholly successful in Europe is not necessarily so in Asia. The main principles will probably be applicable both to East and West, but the details will widely diverge, and to blindly accept in its entirety an English system is to court defeat in an Oriental City.

The prejudices and habits of the people are in many ways opposed to an English system of drainage, while the climate makes paramount the necessity for quicker removal of excrementitious matter. It must also be remembered that Orientals use more water for washing purposes than their brethren in Europe, principally on account of frequent religious ceremonies involving ablutions,

The habit, which obtains with almost all Orientals, of scouring their metal domestic utensils with ashes, sand, or road detritus, adds largely to the possibility of chokage in sewers. These substances when mixed with fœcal matter form a kind of concrete, the removal of which is beset with much difficulty.

The climatic conditions of a tropical country add many difficulties to the satisfactory solution of drainage problems, the temperature being generally such that putrefaction rapidly takes place. A high temperature causes an excessive formation of gas in sewers, and the introduction of sewage gas into dwellings means disease. Consequently especial consideration has to be given to the ventilation of sewers and to the materials used in the construction of sewerage works. The temperature of the ground is also a consideration, and where the range is great, even stoneware pipes are susceptible to it. In many Indian Cities the range is very great, in some extending from below freezing point to above 110°. In Bombay, which is singularly equable for India, the extreme maximum temperature of air observed during the last 50 years was 100·2° and the extreme minimum 53·3°, but the ground temperature varies little. The temperature of the water supply probably decides that of the sewage and is also generally that of the sub-soil water.

The gradients of sewers which are considered in Europe to give sufficient velocity for the removal of solids are, as will be shown hereafter, insufficient in India. There is, too, the additional disadvantage, as before pointed out, of the presence of materials used for cleansing domestic utensils, and the fact that public and private latrines have to deal with quantities of stones, broken tiles,

and rags, much of which finds its way into the public sewers.

The old time practice of building houses in Indian Cities so close together as to be detached only in name, adds enormously to the difficulties of house drainage, as also the fact that nearly all Hindu castes use dry leaves for plates which are disposed of, some by being thrown into the washing places which exist in the corners of most rooms, and some into the narrow gullies or passages which lie between the houses, whence they find their way into the house drains.

Rainfall is a considerable factor in dealing with sewage. The rainfall of India varies in places from 600 inches per annum to nothing; but the fall in Bombay is fairly regular as will be seen by the following figures, obtained from the Colaba Observatory, which give the annual rainfall from 1843 to 1901, inclusive :—

	Inches.		Inches.		Inches.
1843	55·24	1863	77·68	1883	90·18
1844	62·71	1864	45·56	1884	75·44
1845	54·12	1865	77·85	1885	67·91
1846	73·93	1866	78·44	1886	99·74
1847	76·00	1867	62·30	1887	94·95
1848	75·86	1868	62·12	1888	57·82
1849	114·89	1869	91·66	1889	67·84
1850	50·25	1870	66·21	1890	65·18
1851	96·07	1871	40·58	1891	77·18
1852	69·27	1872	76·48	1892	95·42
1853	62·60	1873	69·70	1893	67·24
1854	82·14	1874	82·18	1894	66·85
1855	41·18	1875	83·09	1895	67·59
1856	65·92	1876	50·04	1896	87·65
1857	51·27	1877	69·89	1897	81·53
1858	62·45	1878	111·93	1898	74·09
1859	77·16	1879	61·40	1899	35·90
1860	62·15	1880	67·94	1900	69·12
1861	79·91	1881	73·04	1901	75·32
1862	73·63	1882	69·23		

The maximum rainfall registered in any one day in these years was 16·10 inches on the 18th June 1886 and the greatest fall in an hour 4·22 inches. Rain in Bombay occurs on an average upon 104 days per annum. During heavy rain the evaporation in Bombay is small, but there is no doubt that at other times it is great. Mr. Baldwin Latham in his report "The Sanitation of Bombay" gives it as much as 62 inches per annum, this figure being determined by calculations based on temperature, dryness of the air, and velocity of the wind. Some years ago Mr. David Gostling, F.R.I.B.A., made some observations in Bombay during twelve consecutive months and found the evaporation to be 51 inches for the whole year. This, however, might have been an exceptional year and does not necessarily disprove the correctness of Mr. Baldwin Latham's estimate.

Of the rain which falls in Bombay with its large number of buildings, paved spaces and metalled roads, the greater portion at once flows off, and the amount, which percolates into the ground, according to Mr. Baldwin Latham, does not exceed on the average 9 inches during the monsoon.

House connections in an Indian City are always a matter for grave consideration ; as under no circumstances can they be installed satisfactorily at a small cost, and because of the generally cheaper construction of buildings in the East than in the West and the consequent disproportion which often exists between the cost of a building and of its connections. It has not been unknown that the cost of a house connection has exceeded the value of the building concerned.

It is the experience of Bombay that the branch drain which connects a house with a sewer should, if possible,

be an open drain, as open drains, though not cheaper than closed, have the advantage of being easily cleaned and generate no sewage gas.

A fact, which cannot be too strongly insisted on, and one which may be considered an axiom in Sanitary Science, is that a water-supply should not be brought into a town, unless efficient arrangements have been made for its removal immediately it has served its purpose, and if this applies to the West, how much more should it apply to the East with its increased temperature?

The following is not an unfair description of many a mofussil town in India. A confined area, teeming with a dense population, the houses huddled together, along for the most part narrow alleyways rather than streets; with few latrines and with very little attempt at sweeping, the refuse being generally taken no farther than the nearest open space and the sewage finding its way to a convenient tank or soaking into the ground. In such circumstances the problem of a complete and satisfactory drainage scheme is by no means easy to solve.

The Author hopes that the effort made in the following pages will be of use to Engineers in dealing with such problems.

ORIENTAL DRAINAGE.

CHAPTER I.

Drainage Systems.—Until comparatively recent years little or no attempt had been made to cope with the sanitation of towns in India. Often the want of a regular water-supply and the poorness and indifference of the inhabitants were responsible for this.

Open drains at the sides of streets and the yearly cleansing by the monsoon rains were to a large extent the drainage system depended on.

But the growth of education and greater prosperity have created a demand for better sanitary surroundings, and the bitter lesson, which the plague has taught in many cities, has shown the authorities and the people the blessings and comforts of sanitation.

The passing of Municipal Acts by Government has created local authorities who have full powers to compel sanitary measures being taken by the people themselves; and all the large cities have either now laid down, or are preparing to lay down, some modern system of sewerage, and while in former years it was necessary to import from Europe almost all sanitary pipes and fittings required for sewerage schemes, great facilities are at present afforded to Local Bodies in the selection of these appliances, as most of them are now easily obtainable locally made from such

firms as Messrs. Richardson & Cruddas of Bombay, or Messrs. Burn & Co. of Calcutta.

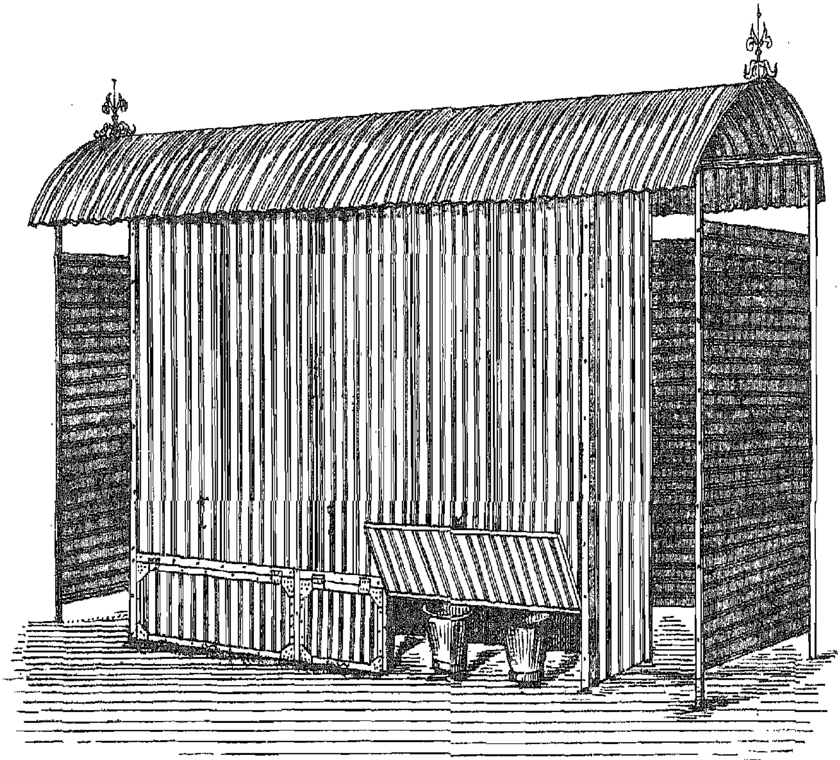
Sewerage systems may be conveniently classed under three heads, *viz.*,

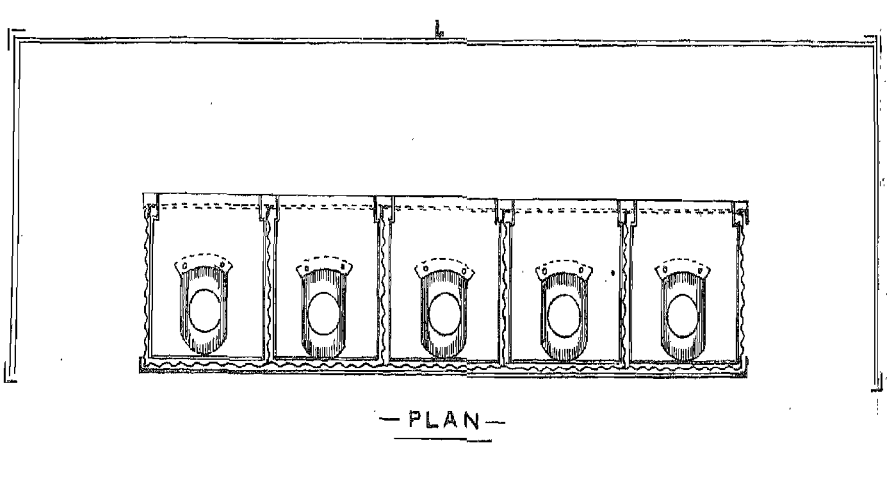
(*a*) Hand removal,
(*b*) Gravitation,
(*c*) Pumping.

Hand Removal.—One of the earliest attempts towards any drainage system was undoubtedly that of "hand removal," or as it is usually called the "conservancy system," and under this head must be included the emptying of cesspools and the removal of night-soil by hand. In places, where no modern sewerage system exists, cesspools are a necessity for the collection of sullage, which is subsequently removed to and disposed of in the nearest nullah or river or applied to the land, while the night-soil is taken to a convenient spot outside the village or town and dug into the ground.

In most Indian towns and villages this system still exists, and even in Bombay there are parts of the Island not yet connected up with the main sewerage system where cesspools and dry privies are still in use. The night-soil from such privies is removed by hand once in twenty-four hours to the nearest night-soil depôt on the main system of drainage and discharged into a sewer. This operation will be more fully described hereafter. The sullage is removed from the cesspools by means of buckets or pans and placed in closed iron carts, which are ultimately emptied in the same way into sewers at convenient points.

There is no question as to this method being insanitary and objectionable because (*a*) of the non-removal of



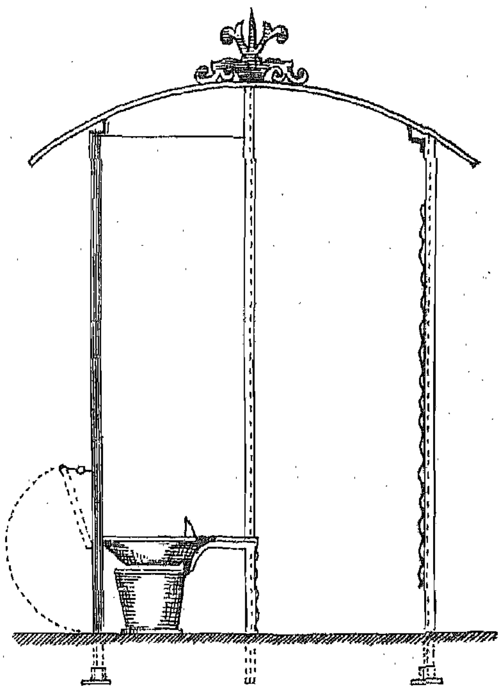


— PLAN —

PLATE I

HORBURY'S PATENT PRIVIES

FOR NATIVES

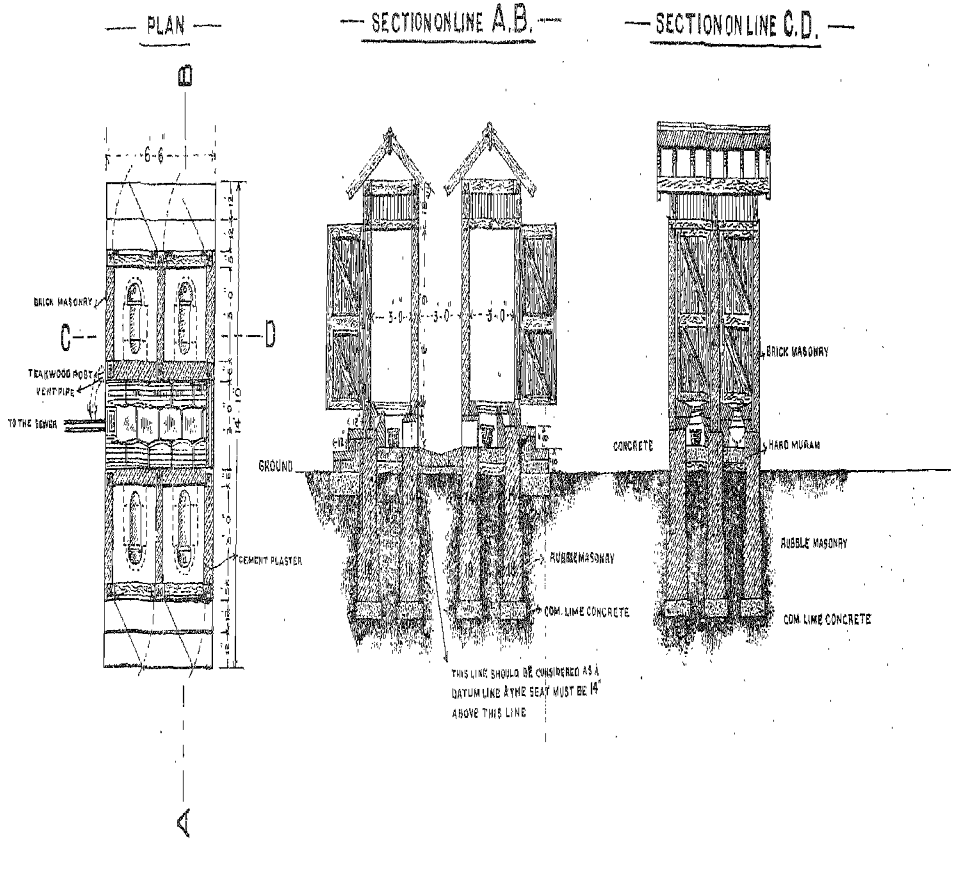


CROSS SECTION

PLATE 2

STANDARD DESIGN FOR LATRINES ON THE BASKET PRINCIPAL

SCALE 6 FEET TO 1 INCH



sullage and fœces for several hours from the vicinity of buildings, (*b*) of the passage of sullage and night-soil carts through closely-inhabited streets, and (*c*) of the emptying of these carts at various depôts, liberating a large amount of offensive and dangerous gases; but it is not every town or village that can afford the luxury of a more up-to-date Sewerage System, and such attempts are better than leaving refuse of every description to putrify in the open air.

A good type of an undrained privy is the one well known as the Horbury Pattern Privy made by Messrs. Richardson and Cruddas, Bombay. Plate 1 shews a range of these privies. They are constructed entirely of corrugated iron sheeting fixed on an angle iron framing and to a concrete floor. Instead of seats squatting plates are provided, made of cast iron in one piece with a shield to prevent the splashing of urine. The night soil and the fluid matter are discharged into an iron bucket, usually well tarred or dammered, which is easily removable by the lifting of a door at the back. These privies have been in use for several years and have given satisfaction.

Plate 2 shows an ordinary type of privy much in use, constructed of wooden posts and brick masonry. In this privy the solid matter is retained in a cane basket about 15 inches in diameter and 12 inches high, the interstices of which allow fluids to pass out and flow over the cemented floor into a trap fixed on a pipe drain which is connected to a cesspool. The cesspool should be constructed under ground of brick masonry, plastered with cement, and of a capacity, below the level of the inlet pipe, equivalent to 3 cubic feet for every seat of the privy. It is covered with a cast iron or wooden cover and is

ventilated by means of a 3-inch cast iron pipe fixed in a convenient position and finished with a T head.

Another useful type of a privy is that known as the "Aryan Patent Latrine" made by Messrs. Marsland Price & Co., Bombay, shown in Plate 3. The "Aryan" is in construction similar to the "Horbury," but the arrangement for the receptacles is somewhat improved. It is claimed that this privy is in advance of previous types, as it allows for the separation of the fœcal matter from the fluids, and also that there is no fear of the users being splashed from below, there being little or no fluid in the pan. The privy is also constructed with a specially shaped potteryware shoot instead of the usual iron one.

It may be mentioned that the Natives after stooling use water instead of paper, while some races make use of stones which are then disposed of in the privy.

Gravitation.—There are various kinds of gravitation systems of drainage in use, and it is necessary, before preparing a design for the sewerage of a town or city, to carefully decide on the system to be followed. What is known as the "combined system," in which both sewage and surface water are removed by one sewer, is not applicable generally to a country like India. The seasons in India are well defined, the rainfall being restricted to practically only four months of the year, and where that rainfall exceeds 30 inches, it is impossible to design sewers capable of being self-cleansing in the dry weather, and at the same time large enough to dispose of the surface water in the monsoon. Sewers constructed larger than necessary for the sewage proper will soon become charged with deposit in the dry weather and prove highly injurious to health.

ATRINES —

PLATE 3

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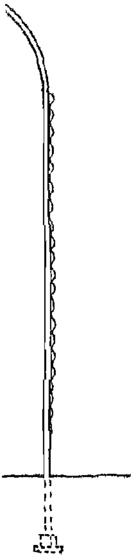
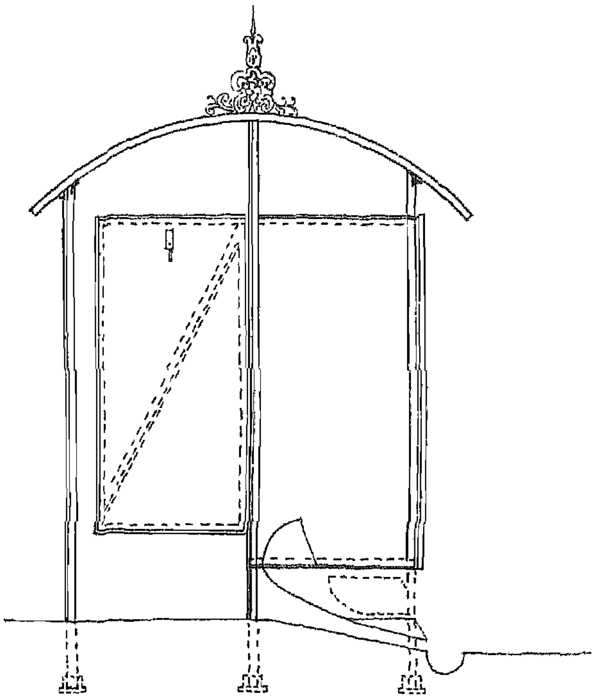
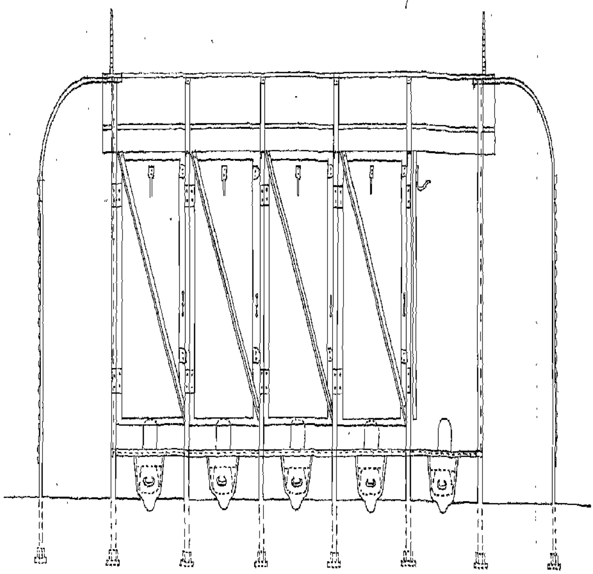




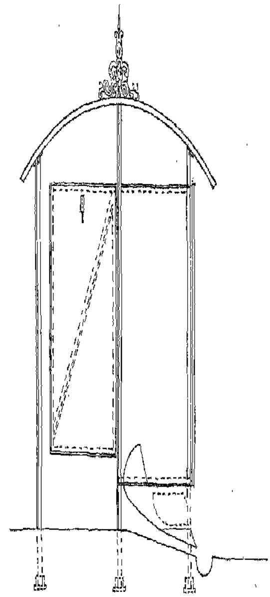
— CROSS SECTION —

"ARYAN" PATENT NATIVE LATRINES

SCALE 3/8 OF AN INCH TO A FOOT



ELEVATION



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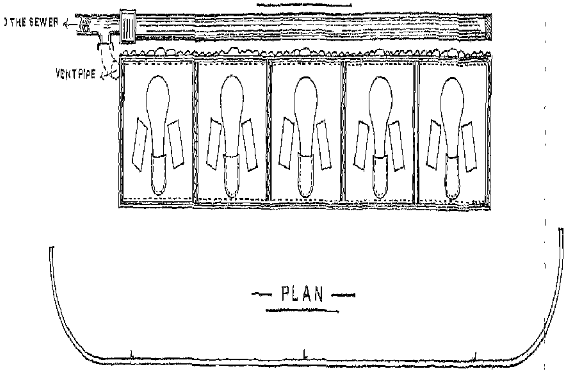


PLAN

The "separate" system, which disposes of all the sewage and such an amount of rain as falls in small courtyards and sweeper passages or gullies, is the best for India. Much smaller sewers can be used in this system and greater facilities are afforded for supervision and cleansing, while the formation of sewer gas is at the same time minimised ; on the other hand, however, it involves the extra cost of a complete double set of drains or pipes, one for sewage and one for surface water, and in some places such as Bombay for subsoil water also.

The Author's experience leads him to prefer dealing with the subsoil water in conjunction with the surface water, and in spite of the extra cost so incurred keeping all sewage matter in sewers set apart for the purpose.

Having decided on a "separate" system of sewerage, a carefel study of the ground and its natural drainage should be undertaken before laying down the route of the main sewers. Generally it will be found advantageous to run them along the valley or in the direction of the natural fall of the town. This having been determined, the next point to be decided is the outfall or position to which the sewage is to be delivered, and generally lifting or pumping will be found necessary. A natural outfall into a river or sea and discharging wholly by gravitation is the ideal rarely obtained. The alternatives to this are, therefore, either pumping or impounding during intervals between tides, but the latter may be in many ways objectionable, particularly in the high temperatures of tropical climates, because of the rapid formation of gases.

In designing a pumping system, gradients should not be sacrificed in order to reduce lift. As however every additional foot of lift means extra initial and annual

expense, the greatest care should be given to selecting the position of the outfall, so that the utmost possible advantage may be taken of the existing natural conditions.

At the same time, it must be remembered that every size and shape of sewer has its own self-cleansing gradient, and this must be looked upon as an essential and on no account, as stated above, sacrificed even at the expense of increased lift.

In fixing the gradients of sewers, it is as wrong to give too steep a gradient as too flat a one. In the one case a liability to wearing action which destroys the inside surface of the sewer is the result, and in the other a precipitation of solids and all the difficulties and evils caused thereby. A fair sample of deposit in an Indian sewer would be a collection of road detritus, broken bricks, road metal, rags, cotton, etc. This point and the actual disposal of sewage at the outfall will be dealt with in a subsequent chapter.

Pumping.—Where a town is so circumstanced that the whole of its sewage will gravitate to one point, but at too low a level to admit of free discharge, the pumping of sewage can best be effected by a direct acting pumping engine; but it is generally necessary to divide the whole area into sections and automatically lift the sewage of each section by means of power generated at a central station. This power may be distributed by either compressed air, water under pressure, vacuum, or electricity.

The type of engine, which is probably most economical in installations requiring not more than 25 brake horse power, is an oil or gas engine connected by gearing to two or three-throw vertical ram pumps, with externally packed

plungers. Above these requirements steam is generally to be preferred on account of its greater adaptability to a varying load. If an oil engine be selected, one of the several types which are adapted for burning 125° Bulk Kerosine Oil should be chosen, not only because of the greater economy of this oil, but also because it is now freely obtainable everywhere.

For high or even moderate lifts necessitating the pumps being placed below ground level, there is a choice of the beam, the marine or other type of vertical engines, of which the Worthington is a good example, coupled direct to the pumps below, or horizontal engines connected to the pumps through the medium of a crank placed in a frame above the pump well.

For low lifts the Worthington direct-acting horizontal pumping engine, or a centrifugal pump coupled direct to a high speed horizontal or vertical engine, is suitable, but the latter is not to be recommended for sewage pumping unless the total lift is under 25 feet, and though it is cheaper in first cost, its efficiency is low.

Vertical ram pumps are subject to less wear than horizontal pumps, as grit which, as has been already pointed out, is always a special trouble in the East, does not lodge so readily on the moving parts of the former. Pumps of the bucket and plunger type are not as suitable for pumping sewage, as are ram pumps, on account of the grit causing excessive wear between the bucket and the pump barrel. The valve area in a pump of this type is also of necessity very restricted—a feature which is extremely undesirable where a liquid like sewage has to be dealt with. With ram pumps the valves can be so arranged as

to be entirely independent of the ram, and can thus be made of sufficient area.

Now that there would appear to be an unlimited supply of Petroleum Liquid Fuel in both the Eastern and Western Hemispheres, it is probable that it will rapidly be adopted, in preference to coal, by Municipalities for use in Pumping Stations situated within and beside large cities. With its use the nuisances from dust, smoke, soot, and ashes are, with ordinary care, entirely obviated—an important consideration to Municipalities, whose duty it is to set an example in such matters. Liquid Fuel is composed of a variety of substances, but that which is most largely used is crude Petroleum or the residue of Petroleum after refinement. Its flash point ranges from 150° to 210° Fahrenheit, and its calorific value as compared with coal ranges from $1\frac{1}{2}$ to 1 to upwards of 3 to 1. About $1\frac{1}{10}$ pint of oil is required per horse-power per hour.

Pneumatic System.—Local circumstances often require the sewage from several outlying portions of a city to be lifted or pumped, while the major portion of the sewage has a natural outfall. In such cases Shone's Hydro-Pneumatic Ejector System is economical and useful. In this system the motive power is compressed air, which is carried in small pipes to various points and there utilized to effect the required purpose. The system can, of course, be also applied when the whole of the sewage has to be lifted, and the Patentees claim special advantages in this contingency; but it is doubtful whether it would not be more economical in such cases to perform the work by direct pumping.

The following are the advantages claimed by the Patentees of this System and published by them. Many

SHONE'S PNEUMATIC EJECTOR.

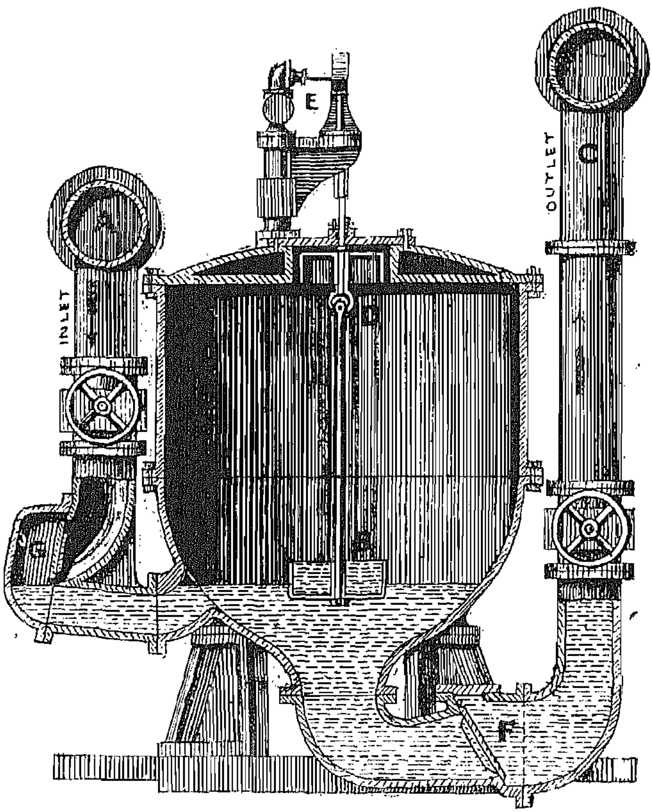


FIG. 1.

of them the Author would be in full agreement with, but others are not so apparent as the Patentees appear to set forth :—

(1) The interception of the bulk of the sewage at higher levels and consequent saving of power as compared with a single pumping station in which the whole has to flow down to the lowest point, the continued fall to the pumping station being so much absolute waste power.

(2) The entire severance of each district from the main collecting sewers and the rest of the drainage area ; thus in the event of any epidemic disease breaking out in one district, it cannot be conveyed by sewers into healthy districts, as is often the case when the whole area is connected by a net work of drains leading to a common outfall.

(3) The avoidance of deepcuttings and of large sewers whereby great economy is effected in first cost.

(4) The ready extension of the system in proportion as the population and occupied area increases, thus avoiding the immediate provision for probable future requirements and relieving the rate-payers of the present day of the heavy burden of providing prematurely for the want of a possible future population.

Fig. 1 gives a sectional view of a Shone's Ejector. These ejectors are all constructed by Messrs. Hughes and Lancaster. They are made of varying sizes, from 50-gallon capacity upwards. In Bombay there are several working, from 100 up to 1200 gallons capacity each. An ejector consists of a spherically-ended container made either of cast

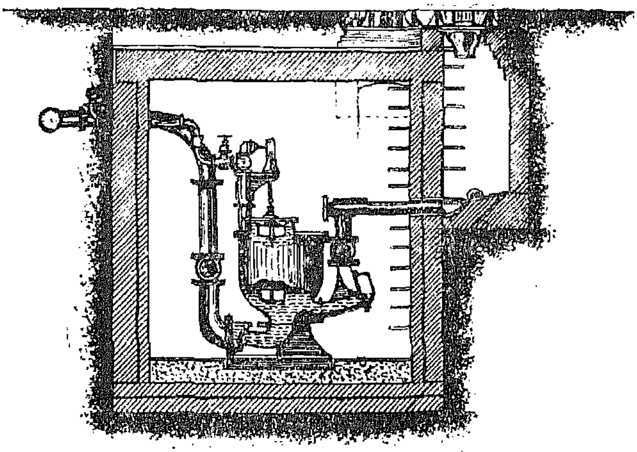
or wrought-iron and placed in a brick-work chamber, as shown in Fig. 2, or in a cast-iron tubbing as shown in Plate 5. The working of an ejector is very simple, as will be seen by a reference to Fig. 1. The sewage enters by gravitation through the pipe A, passes the flap G and enters the container. The sewage rises until it reaches the underside of the bell D; the air within the bell is then enclosed and the sewage continuing to rise compresses the air until it can raise the bell D with the rod and cup B, sufficiently to slide the valve E so as to admit air from the air main. As soon as the air is admitted, it is free to act on the surface of the sewage in the container. The pressure so applied closes the back-pressure valve G and forces the sewage past the flap valve F into the pipe C and thence into the sealed sewage main, the sewage being thus driven out of the ejector.

The sewage in the cup B cannot, however, escape, and its weight, when the sewage falls below the cup, is sufficient to lower the spindle with the bell thereby re-sliding the valve E, so as to close the mouth of the air-supply pipe, and open that of the exhaust pipe through which the compressed air in the ejector escapes into a shaft hereafter described. The outlet valve F then falls on to its seat owing to the weight of the sewage in the sealed sewage main and retains the liquid in that main and the ejector commences to fill again. This process is repeated automatically so long as there is any sewage to flow into the ejector.

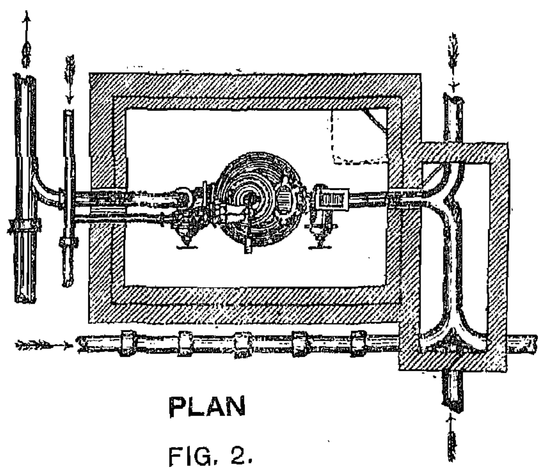
The compressed air for working the ejectors is produced in a central station, located in a position to suit all the ejectors, and is conveyed to them in cast iron pipes laid in the streets at a depth of some 3 feet, where

SHONE'S PNEUMATIC EJECTOR

IN BRICK CHAMBER.



SECTION



PLAN

FIG. 2.

they are free from all danger of breakage from traffic and steam rollers.

The advantages of the ejectors as given by the Patentees may be summed up as follows :—

(1) The working parts are reduced to a minimum and such as are requisite are not likely to get out of order.

(2) The parts with which sewage comes in contact contain no machine-tooled surfaces, which are unavoidable in pumps and get rapidly destroyed by the action of sewage, sludge and grit from the road detritus, etc. In the ejectors there is nothing but the hard skin of the original castings, coated with Dr. Angus Smith's composition, upon which the sewage can produce no detrimental effect.

(3) The friction of a pump piston and other working parts are avoided, the compressed air itself acting direct upon the fluid, without the intervention of any machinery, and forming an almost absolutely frictionless and perfect piston past which there can be no slip or leakage.

(4) The cup-and-bell float arrangement is one that cannot possibly get out of order, as an ordinary rising and falling float would be likely to do.

(5) The only tooled parts are those in connection with the small automatic air valve ; this makes only one movement of two or three inches for each discharge of the container of from 50 to 1,200 gallons (according to the size of the ejector), and is only in contact with the compressed air and out of reach of the sewage.

(6) The sewage inlet and outlet valves are so arranged as to give free passage-way of the full area

of the pipe, allowing a free passage to all solids that the pipe itself can carry. No part of the container has any depression or traps wherein solid matter can collect.

(7) The outlet is from the bottom of the ejector, so that the whole of the sewage, including solids, sludge, grit, and everything brought down the sewer, is discharged out of the ejector.

(8) For these reasons no screening or straining of the sewage is necessary, as is the case with pumps, and the great nuisance caused by the cleaning of pump gratings and sump wells is avoided.

(9) The sudden rush of the whole contents of the ejector when the discharge is into a main gravitating sewer forms a most effective flush.

(10) The ejector forms an absolute severance of the sewers of each district from the main sewer.

The size of an ejector required for any district is determined by the estimated quantity of the sewage of the district, its capacity being equal to the number of gallons of sewage per minute at the time of maximum flow, which, as is explained later, is one and a half times the average per minute of the total daily flow. Each district should be provided with ejectors of the requisite size in duplicate, one being sufficient to cope with the ordinary work, the other being held in reserve. The two ejectors should be worked alternately, say, every week or fortnight, to ensure that they are both kept in working order.

Cast iron pipes required for air and sealed sewage mains need not be of the same thickness as those used for water works, as the pressures under which they work are

comparatively light. The following thicknesses are recommended for these mains :—

Diameter :	$2\frac{1}{2}''$	$3''$	$4''$	$5''$	$6''$	$7''$	$9''$	$10''$	$12''$	$14''$	$15''$
Thickness :	$\frac{3''}{8}$	$\frac{3''}{8}$	$\frac{3''}{8}$	$\frac{13''}{32}$	$\frac{7''}{16}$	$\frac{1''}{2}$	$\frac{9''}{16}$	$\frac{9''}{16}$	$\frac{5''}{8}$	$\frac{5''}{8}$	$\frac{11''}{16}$

The weights of pipes of these thicknesses, 9 feet long, exclusive of the socket, would be as follows :—

	cwts.	qrs.	lbs.
$2\frac{1}{2}''$ diameter	...0	3	22
$3''$,, ...	...1	0	10
$4''$,, ...	...1	1	20
$5''$,, ...	...1	3	24
$6''$,, ...	...2	1	27
$7''$,, ...	...3	1	1
$9''$,, ...	...4	2	24
$10''$,, ...	...5	0	16
$12''$,, ...	...6	3	13
$14''$,, ...	...8	0	25
$15''$,, ...	...9	2	3

The air mains, after being laid and covered in, should stand a test of not less than $1\frac{1}{2}$ times the working pressure of air for two hours, with a loss not exceeding 20%.

They should be tested periodically , and when found to lose more than the above limit in *one* hour steps should be taken to stop the excess leakage. To do this, each section should be tested separately, having previously examined all stop valves and made arrangements for fixing a pressure gauge to the main in each section.

After the section, in which the excessive leakage has taken place, has been located, the air should be blown off, and about 1 lb. of concentrated oil of peppermint, or other strong smelling volatile oil, should be introduced into the pipe by removing the stop valve cover at the end of the defective section nearest to the compressor station,

On restoring the pressure, the air contained in the pipe will be heavily scented, and if the latter is not laid at a greater depth than 3 feet, the position of the leak can generally be detected by carefully walking over the site of the pipe.

An early hour on a still morning should be chosen for the test, and it is scarcely necessary to state that the person conducting it should *not* himself place the essence in the pipe.

If this means of detection fails, the pipe will have to be cut in the centre of the section and each half tested separately, and so on in the same manner until the leak is confined to a comparatively short length, the whole of which can then be exposed. The leak will generally be found to be due to a cracked pipe, a blown joint or a section of piping having settled in soft ground. Leakage in exposed joints, which are only slightly defective, can be ascertained by washing them over with soap and water, when the escaping air will blow small bubbles round the leak.

The following is a simple and practical rule for calculating the sizes of air and sealed sewage mains :—

> It will be correct for all practical purposes to lay the sewage delivery pipes, so as to carry sewage at a velocity of $2\frac{1}{2}$ feet per second, and the air mains to carry compressed air at a velocity of 20 feet per second.
>
> Divide the capacity of the ejector in gallons by twice the above velocities (in feet per second), and take the square root of the quotients. The results will give the diameter of the respective pipes in inches.

D=Diameter in inches,
G=Capacity of the ejector in gallons.
V=Velocity in feet per second.

$$D = \sqrt{\frac{G}{2V}}$$

The following example will illustrate the above rule :—

What should be the size of the ejectors, the air main, and the sealed sewage main for a district having a population of 12,000, 6 cubic feet per head per diem being taken as the average water-supply?

Population of district = 12,000.

Average water-supply per day = 12,000 $\times$ 6 cubic feet or $\times$ 37.5 gallons = 450,000 gallons.

Gallons of sewage per minute = $\frac{450,000}{24 \times 60}$ = $312\frac{1}{2}$ gallons.

Quantity at time of maximum flow = $312\frac{1}{2} \times \frac{3}{2} = 469$ gallons.

An ejector of 500 gallons capacity would therefore be required, and as one ejector should always be a stand-by, two ejectors of 500 gallons each should be provided. As regards the sizes of the mains, the diameter of the air main would be equal to $\sqrt{\frac{500}{2 \times 20}} = 4$ inches (an even figure), and that of the sealed sewage main would be equal to $\sqrt{\frac{500}{2 \times 2 \cdot 5}} = 10$ inches.

The air pressure required to operate any particular ejector is calculated as follows :—

Suppose the level of the bottom of the ejector is 60 feet above any datum, and that of the end of the sealed sewage main, where the sewage is finally discharged, 90 feet above the same datum. The height

through which the sewage is lifted would be 90—60 = 30 feet.

Suppose the sealed sewage main to be 10,000 feet in length from the ejector to the outfall, the diameter 12 inches, and the velocity $2\frac{1}{2}$ feet per second; the discharge would equal about 107 cubic feet per minute, and calculating from Taylor's Pipe Discharge Diagrams the frictional resistance would amount to 2·8 feet per thousand or a total of 28 feet for the whole length. Therefore the total head to be overcome is equal to 30 feet the actual height and 28·0 feet the head due to friction or 58·0 feet in all.

It requires an air pressure of 1 lb. per square inch to overcome a head of 2·3 feet of water, and therefore the pressure in the ejector to overcome the above resistance and drive out the sewage must be $\frac{58 \cdot 0}{2 \cdot 3}$ or 25·21 lbs. per square inch.

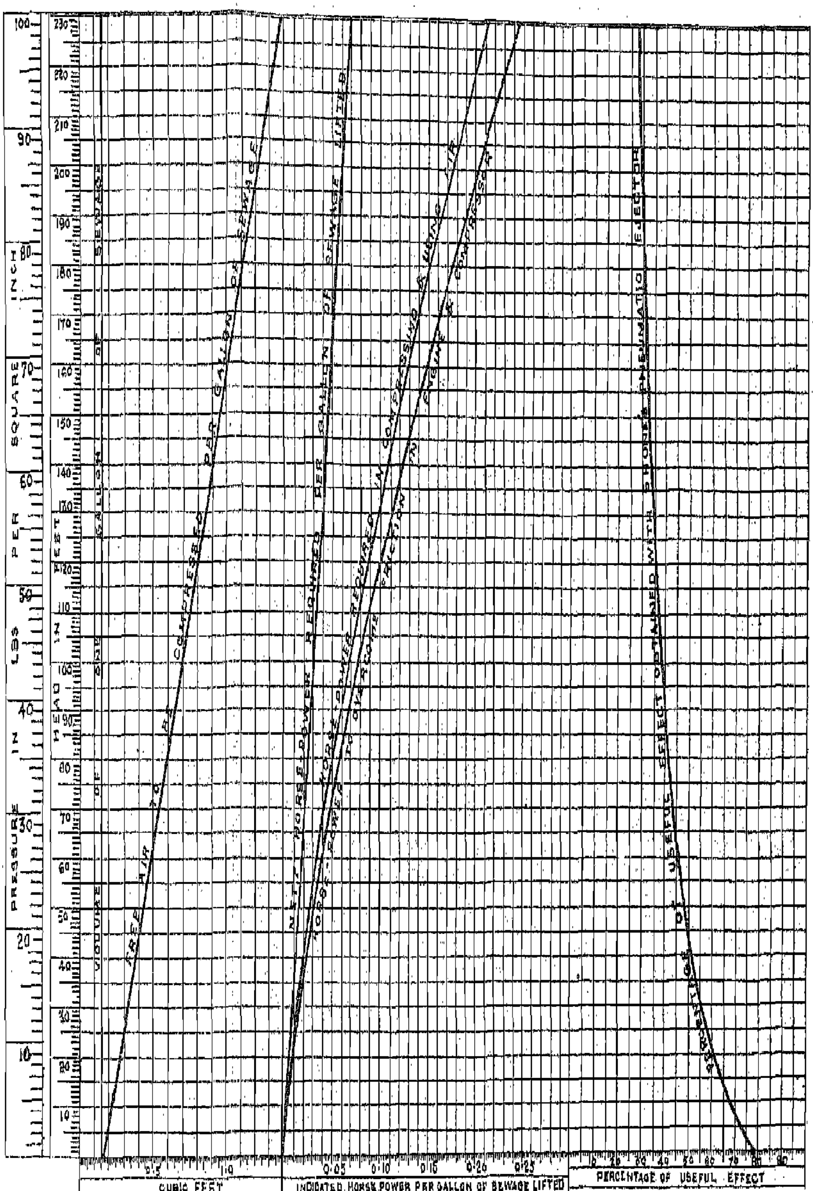
The accompanying diagram taken from a paper read by Mr. Edwin Ault before the Society of Engineers shews :—

(a) The quantity of free air required per gallon of sewage for different lifts.

(b) The indicated horse-power required per gallon of sewage for different lifts.

(c) The percentage of useful effect obtained with Shone's ejectors.

Plate 4 shews how the connections are made between the ejector and the sewers, and the ejector and the sealed sewage or rising main. There are two pipes rising from the top of the ejector, one of these being the air main supplied direct from the engine house, and the other the exhaust pipe through which the compressed air, after

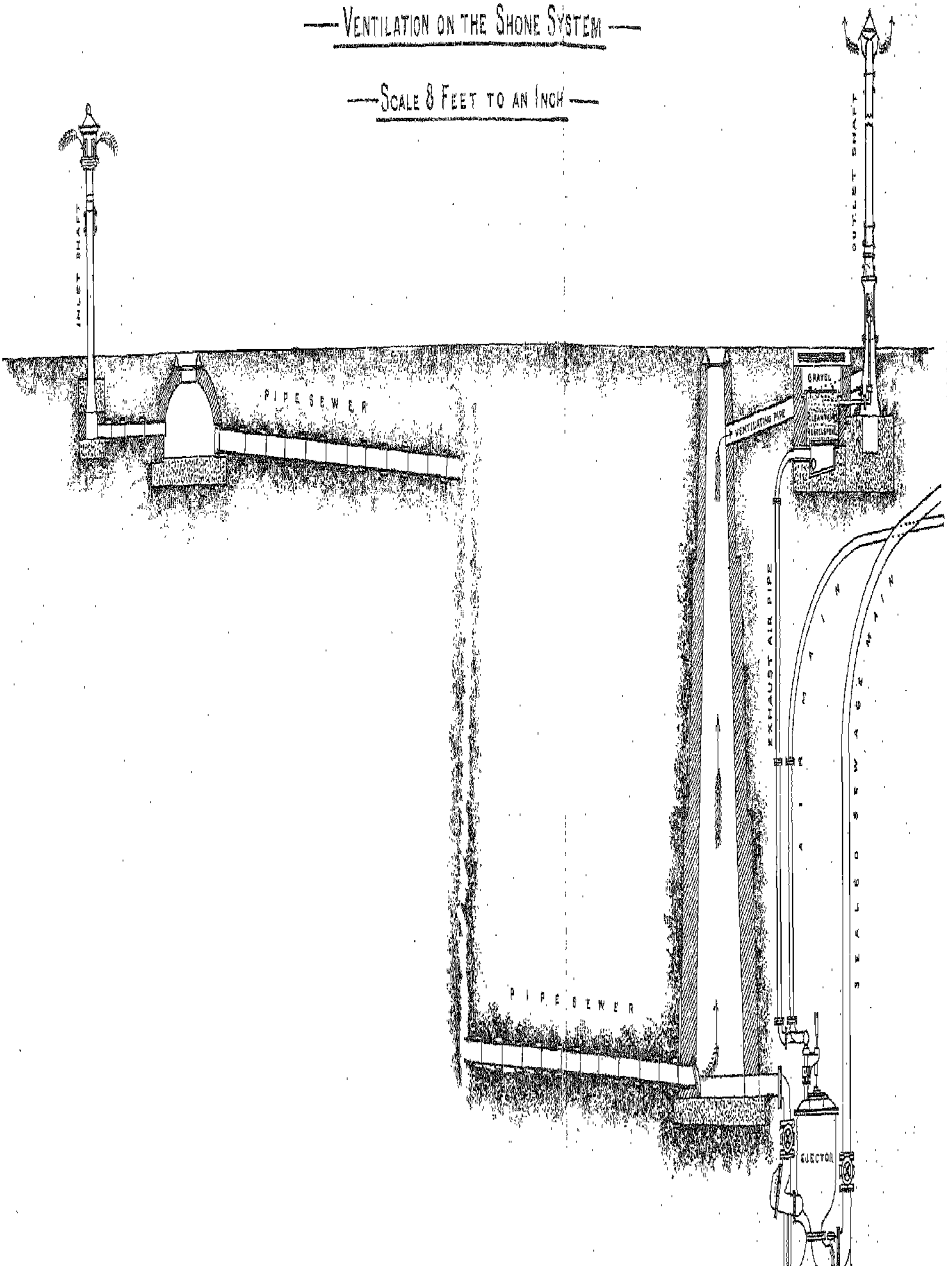


PRESSURE IN LBS PER SQUARE INCH
HEAD IN FEET
VOLUME OF ONE GALLON OF SEWAGE
FREE AIR TO BE COMPRESSED PER GALLON OF SEWAGE
NETT HORSE POWER REQUIRED PER GALLON OF SEWAGE LIFTED
HORSE-POWER REQUIRED IN COMPRESSING & USING AIR
HORSE-POWER TO OVERCOME FRICTION IN ENGINE & COMPRESSOR
PERCENTAGE OF USEFUL EFFECT OBTAINED WITH SHONE'S PNEUMATIC EJECTOR
CUBIC FEET
INDICATED HORSE POWER PER GALLON OF SEWAGE LIFTED
PERCENTAGE OF USEFUL EFFECT

Plate 4

Ventilation on the Shone System

Scale 8 Feet to an Inch



having done its work by forcing the sewage through the outlet of the ejector, is allowed to escape. This exhaust air passes through a layer of coarse gravel before it finds its way out at the outlet shaft. This is an arrangement much advocated by the Patentees to dry the exhaust air before being finally discharged, and is not intended in any way to disinfect the air, for which some material, such as charcoal, would be necessary. The shaft nearest the ejector is the ventilator, into which the exhaust pipe discharges, each ejector chamber being supplied with a shaft of this description generally about 50 feet high. This constitutes the only ventilation the Shone system has. The shaft farthest away from the ejector, shewn in the Plate, is an inlet shaft, and one is usually placed at the head of each length of gravitating pipe sewer. The object of this shaft is to supply fresh air to the pipe sewers, replacing the foul air which is drawn out of them by the action of the exhaust air from the ejector. The sliding openings in the heads of these shafts require to be carefully adjusted, those nearest the ejector chamber being partially opened, while those farther away being fully opened so as to obtain a regular distribution of fresh air.

The ventilating shafts work very efficiently on this system, the exhaust air discharged through a nozzle into the shaft inducing a current and thus drawing a quantity of foul air from the gravitating sewers, but this foul sewer air is very apt to be discharged from the ventilating shafts in puffs and carried by the prevailing wind, long distances, into houses in the neighbourhood. This has been the experience in Bombay, and a serious nuisance has at times been the result. The author is now trying the experiment of burning the gases as they are discharged

from the shafts. There are many reasons which prevent ventilating shafts being raised to any great height, and in the neighbourhood of dwellings it is consequently desirable to treat the gas in some way before it leaves the shaft.

The main air compressor station at Love Grove, Bombay, contains four horizontal triple expansion condensing engines. Each engine has three air-compressing cylinders, the pistons of which are coupled direct to the steam pistons. Two of the engines indicate 220 horse-power each on a full load, and are each capable of compressing 2,466 cubic feet of free air per minute to a pressure of 23 lbs. above the atmosphere. The other two engines are each half the size of the above.

The first cost of the two smaller engines was greater than that of one of the larger size, but in a large installation of this kind, where the day and night loads vary considerably, it is always advisable to have two sizes of engines in order to avoid the loss, which would be occasioned by working a large engine much below its maximum speed.

The two larger-sized engines, or one of the larger and the two smaller-sized engines, when working together, are capable of lifting 14,000 gallons of sewage per minute to heights varying from 17 feet to 44 feet dynamic head.

Steam is supplied by three Babcock and Wilcox water tube boilers, each having 1,426 square feet of heating surface and capable of working up to a pressure of 200 lbs. per square inch.

A Green's Fuel Economiser of 168 tubes is fixed in the main flue from the boilers for the purpose of heating the boiler feed water.

From a purely sanitary point of view, the Shone system is *theoretically* perfect, for the sewage is rapidly removed in a fresh state from the inhabited portions of the town to the ejectors; but in spite of this undeniable advantage, it is not without some drawbacks. In the first instance, it is expensive both as regards efficiency and initial cost, the apparatus required including the air-compressing machinery, the cast-iron air-mains and the sealed sewage mains, and its ejectors and ejector chambers. These, however, are not luxuries but necessities if sanitary conditions are desired and where a gravitation system cannot be adopted. The defects of the system and loss of efficiency are due—(1) to the impossibility of using the air expansively as in steam, (2) the heating of the air during compression, (3) subsequent loss of pressure on cooling, (4) the leakage of air mains, (5) leakage of the valves at the ejectors and (6) the difference in head at the different ejector stations. The efficiency obtained varies with the head to which the sewage has to be lifted, as shown in the diagram facing page 22.

The Shone System, which has been introduced into several districts of the City of Bombay, has so far proved very successful in working. The first installation was put down in the Colaba District in 1895-96, and provides for a present population of 18,000 people and for a prospective population of 28,000. In 1900-1901, a further extension was made for the district of Mazagon, a district having a population of 33,000. In 1901-1902, the system was further extended to the Parel and Chinchpokli districts, having a population of 85,000. Further details of these installations will be found in Chapter VII.

The earliest city in the East to establish the compressed air system was Rangoon, and in the working several defects were met with and rectified, Bombay benefitting considerably by the Rangoon experiences.

There are now 26 ejector chambers, each containing two ejectors, in Rangoon, most of the ejectors being of 200-gallon capacity, and all are, on account of the sandy and water-logged soil, placed in cast-iron tubbing (*vide* Plate 5).

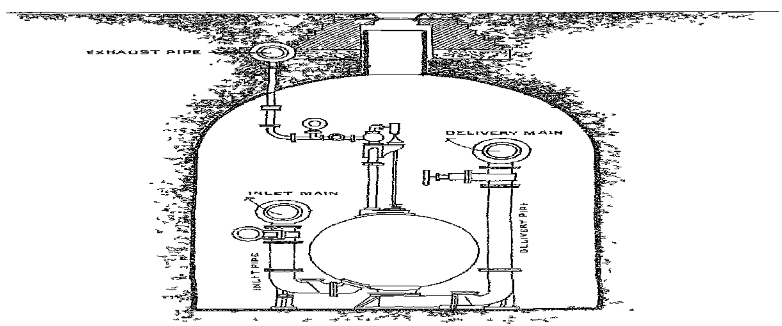
It may be advantageous to describe some of the defects, referred to above, which were met with in the Rangoon installation. In the first place considerable trouble was experienced with pieces of stick, which continually found their way into the sewers from the latrines and interfered with the working of the valves. This difficulty has never been wholly got over, and can only be combated with gratings fixed wherever possible. The sewers are all of cast-iron, 6 inches in diameter; these have always given trouble because of their small diameter, and chokages occurred on an average at the rate of three per day.

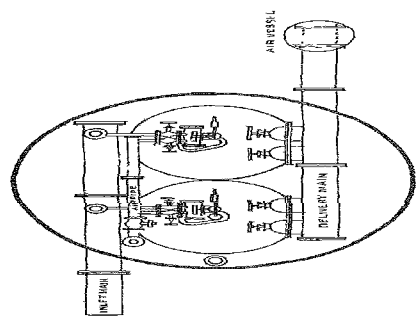
No sluice valve was provided on the outside of the ejector chamber on the discharge pipe to prevent the sewage flowing back from the sealed sewage main; this valve is now always adopted, it being found necessary in the event of the ejector chamber requiring to be cut off from the sealed sewage main.

Another source of trouble was the giving way of the supports and the valve boxes which are cast on to them, caused by the settlement of the cast-iron tubbing. This is now being rectified by the ejectors being bolted to a central cast-iron stand set into concrete. And again,

SHONE'S EJECTORS IN A C.I. TUBBING

SCALE 8 FEET TO AN INCH.





the discharge of the exhaust air into the ejector chambers, instead of being led up a tall shaft and discharged into the open air, once resulted in a serious explosion, doing considerable damage to the chamber.

The want of chambers built around the inspection pipes on the sealed sewage main led to much trouble when a choke occurred, as it occasionally did owing to the sticks before referred to.

The discharge of the air valves at ridges on sealed sewage mains into streets, instead of being carried up above houses by means of pipes, caused an objectionable nuisance.

The inlet valve falling on its seat with a clatter caused excessive vibration to the ejector. This was afterwards overcome by facing the valves with rubber or some similar material.

The want of reducing valves on the air mains to regulate the supply of air in the ejector at a pressure in proportion to the resistance to be overcome resulted in a heavy loss of power.

The want of counters fixed to each ejector registering the number of discharges during each day left unrecorded the quantity of sewage dealt with.

All the above defects were avoided in the first installation established in Bombay.

The total cost of the sewerage of Rangoon on the Shone System came to Rs. 23,52,733, which works out to Rs. 19 per head of the population, or in English money about 26 shillings. This may be considered as a reasonable figure.

The Shone System has also now been adopted in Karachi, which was the first city in India drained on this system. Only the native portion of the city has so far

been sewered on the Shone System. This part is divided into five blocks or sections, containing a population of about 9,000 each. Each block or section has an ejector chamber containing two ejectors of 200 gallons capacity. These ejectors appear to be too small unless the water-supply of Karachi is much less than is usual with an Indian City of that importance, and each ejector should have been of 400 gallons capacity.

For the same reasons as at Rangoon, the ejector chambers here are constructed of cast-iron tubbing. The ventilation of the system is that described in the earlier part of the chapter, *viz.*, one ventilating shaft at each ejector station. The machinery for compressing the air comprises two engines of 25 nominal horse-power, each capable of compressing sufficient air to deliver 375 gallons of sewage per minute from the five ejector stations to the outfall. The outfall for the sewage is on to a sewage farm. The drainage was completed at the beginning of 1895. That the installation has given satisfaction there is no doubt, for it is now proposed to carry out large extensions and sewer the whole of the remaining part of the city except the district known as the Camp.

Hydraulic System.—As an example of the use of hydraulic power for lifting sewage from lowlying areas, which cannot be drained to a general outfall by simple gravitation, may be mentioned the Installation at Woking in Surrey, which was completed in the year 1900. As in the Shone Hydro-Pneumatic System the power is generated at a central station and transmitted through pipes to the various automatic pumping stations which, in the town under reference, are four in number. There were several reasons why in the case of this district the

Engineers, Messrs. John Taylor Sons & Santo Crimp, adopted water-power in preference to air. The principal one was that it was found desirable to place the central station on the sewage farm where the whole of the sewage was purified. The power water has been provided from the subsoil water on the farm, thereby providing an excellent means of assisting to keep the subsoil water at as low a level as possible. A well was sunk on the farm near the engine-house, from which all the water necessary for working the pumps was obtained. The natural level of the water in the well was, on the average, some 6 feet below ground level, and is now, no doubt, being maintained in level by the sewage placed upon the sewage farm. As, however, the effluent coming from the farm is an extremely good one, the water in the well maintains a fair degree of purity.

Another reason for adopting hydraulic power was that the arrangement provided a means of storing the water in overhead cast-iron tanks after it had done its work of pumping the sewage, and subsequently employing it for street watering or sewer flushing. This arrangement at Woking is, as far as the Author is aware, quite a new departure, and has not been utilized elsewhere.

The hydraulic pressure employed is 200 lbs. to the square inch. This is rather a low pressure to adopt for power transmission; but, as has already been explained, there is in this case plenty of water, and in fact the more used the better. The adoption of a low pressure enabled the pipes required for conveying the power from the generating station to the automatic pumps to be of a lighter and less expensive make than they would have been, had the pressure been 1,000 or 1,200 lbs. to the square inch, and reduced the cost of laying and jointing.

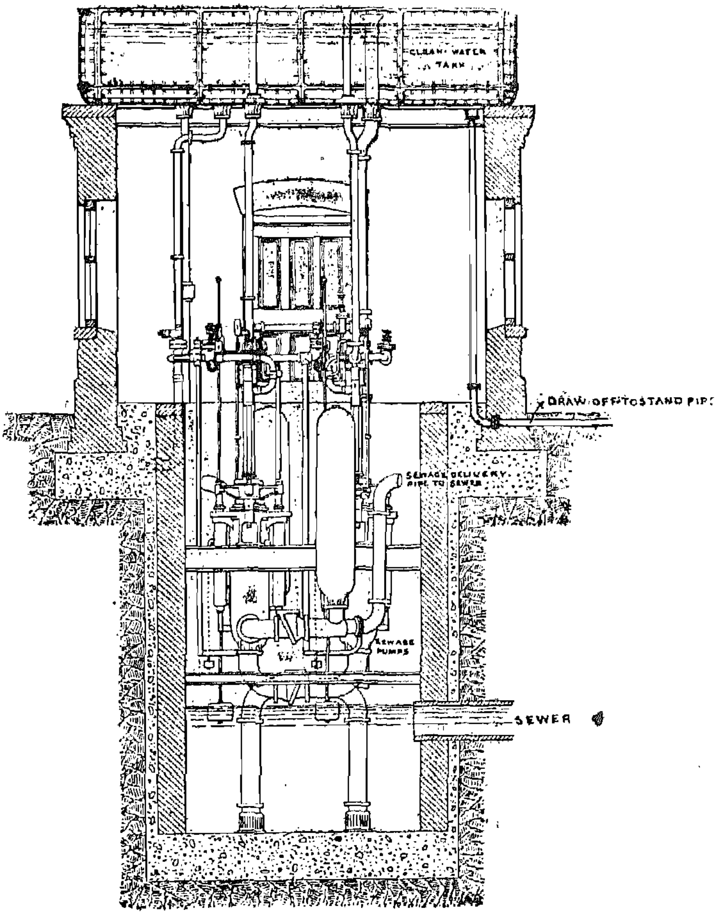
An additional and very important advantage in the adoption of the low pressure is that the size of the accumulator ram can be increased, and so prevent sudden and rapid oscillations when the outlying sewage pumps are automatically opened or closed.

The pipes are of the ordinary spigot and socket type, and the joints were made by first forcing a strip of cold lead into the bottom of the socket and subsequently running the joint with lead and setting up in the usual manner.

The power generating plant at the sewage farm consists of a pair of horizontal compound steam engines, each driving hydraulic pumps direct in line behind the cylinders. These engines work at a steam pressure of 140 lbs. per square inch, and make 90 revolutions per minute. The diameters of the high and low pressure cylinders are 6 inches and 10 inches respectively, both having a stroke of 12 inches. The pumps, which have $4\frac{1}{2}$ inch pistons and 3 inch rams, discharge direct to an accumulator, and from thence the water is forced through the hydraulic main to the automatic pumps at the various outstations. The accumulator ram is 11 inches diameter with a stroke of 10 feet. The rise and fall of the accumulator by means of an equilibrium valve on the main steam pipe, which is connected to a weight suspended directly over the accumulator, automatically admits steam to, or cuts it off from the engines. It is thus only necessary to keep up the pressure of steam in the boilers for the whole system to be in actual automatic working order. The machinery at the various automatic lifting stations, which is shewn in detail in Fig. 3, is in duplicate, and is controlled by means of counterbalanced floats which start or stop the

AUTOMATIC HYDRAULIC PUMPING STATION.

FIG. 3.



Scale, ¼ inch = 1 foot.

pumps according to the level of the sewage in the sumps. The pumps are single acting, the plungers being forced downwards by means of a fixed operating ram, within which slides an operating cylinder. A slide valve worked by hydraulic pressure is alternately placed in communication with the pressure water and with the exhaust. The upward stroke is accomplished by means of two side rams constantly open to the pressure. The plungers of these pumps vary in size at the various stations according to the quantity of sewage to be disposed of, the largest being 2 feet in diameter with a three-foot stroke, the smallest being 1 foot diameter with the same length of stroke. The average lift is 16 feet. The installation, with the exception of the pressure and rising mains, was laid down by the Hydraulic Engineering Company, Chester, and so far the results have borne out the most sanguine hopes of the Engineers.

Margate is another instance where sewage is lifted by hydraulic power, the automatic pumps used being those known as the Latham Davey Hydraulic Pumps. In this case special allowance had to be made for the fluctuating population which, though normally amounting to 20,000, increases to more than three times that number in Summer.

The sewage is on the "separate" system, pumping being only used when gravitation fails. The sewage, after being raised by the hydraulic pumps, is discharged into a high level sewer. The high pressure water for these pumps is obtained by means of a pair of Worthington direct-acting high pressure engines. The full hydraulic pressure is 700 lbs. per square inch. The accumulator cylinder contains a 4 inch ram weighted to 6 tons. There are three pumping stations at different points, the lifts

being 19, 28, and 38 feet respectively. Each pump can work twelve strokes per minute, delivering 40 gallons per stroke.

Vacuum System.—The Liernur "Improved" Pneumatic Sewerage System is one which has been introduced in some few towns on the Continent, and the Syndicate working the patent are now engaged in constructing at their own expense an installation at Stanstead in England.

By this system all the sewage is conveyed through iron pipes to a hermetically closed sewage collecting chamber, by the creation of a partial vacuum in the latter. The term used by the Syndicate for this arrangement to convey the drainage of the district is "Pneumatic Sewer-net." This "sewer-net", or system of pipes, does not in any way deal with the surface water or sullage, but is meant to receive and convey only the fœcal matter and household slops, which are collected, after passing down the soil pipes, in a small cast-iron siphon tank hermetically closed and placed below them.

From each siphon tank there is a cast-iron branch pipe which joins a cast-iron street sewer placed in the road. The town to be sewered is divided into a number of districts, each with a population of about 3,000. In the centre of each district there is a cast-iron underground reservoir, which is called a "district reservoir," and to which all the cast-iron street sewers are connected.

Every day by the operation of valves, these "district reservoirs" are put in communication with the street sewers, and under the pressure of the external air, the fœcal matter in the house tank siphons is carried to the "district reservoirs" and thence on to the collectors, and

LIERNUR'S SYSTEM.

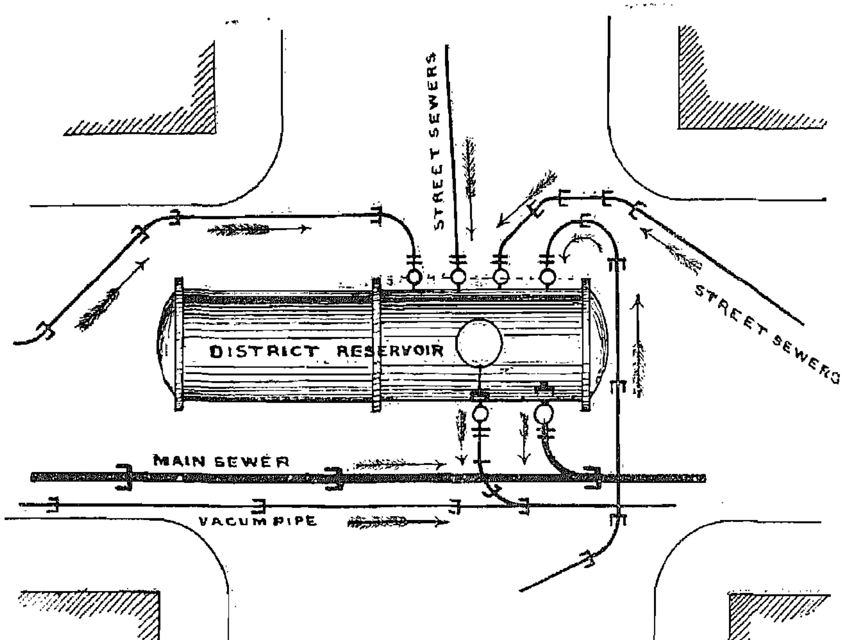


FIG. 4.

finally to a central reservoir placed at the pumping station.

The "district reservoirs" are joined by a series of pipes called main collectors and the main collectors to the central reservoir at the pumping station, situated preferably outside the town, and which contains the necessary pumps to create a vacuum in the whole of the system. It follows that an indispensable condition for the proper working of the system is the absolute airtight condition of the whole of the "sewer net-work;" the motive power being atmospheric pressure. There is said to be no communication with the external air except through the soil pipes which are supposed to act only as air inlets, but considering that each house is only put in connection with the vacuum for a few minutes each day, it is clear that the soil pipes must act as air outlets for the majority of the 24 hours. An advantage claimed in this system is that pipes may follow the contour of the ground, no fall being necessary. Fig. 4 shews the general arrangement of a "district reservoir." The sewage of the whole town is said to be thus driven in a few hours (the working of each "district reservoir" requiring only from 12 to 15 minutes) into the central reservoir at the pumping station, where a sufficient quantity of sulphuric acid is added to the mass to fix the ammonia.

The resultant liquid is afterwards evaporated, and the solids left are finally dried and sold as "Poudrette", for which a high manurial value is claimed. The expense of the production of the Poudrette is very large and expensive plant is also required, and this process of purification cannot be recommended where the manurial value of the sewage can be obtained in its liquid form.

Electrical System.—The adoption of electricity as a motive power for lifting sewage is of comparatively recent date, and only a few such installations are as yet at work.

It stands to reason that in towns, which have electric tramways and electric light and possess any surplus power, it would be both desirable and economical to make use of this power for lifting sewage, if such lifting be necessary.

Electricity can, as is well known, be transmitted great distances at little cost beyond the initial outlay upon the cables, so that in other places where sufficient water power can be obtained all the year round at a convenient distance from the point where the sewage is to be lifted, it may be economical to install turbines and electric generators at the source of power and electric motors coupled to pumps at the pumping station.

One of the earliest electric sewage pumping installations was laid down at Coombs, near Stowmarket in Suffolk, England, by Messrs. John Taylor Sons and Santo Crimp.

The drainage of Coombs, which is only a small village, was undertaken in conjunction with that of Stowmarket and Stow Upland, the sewage from both places being disposed of on a sewage farm. This farm being on a higher level than the village of Coombs, it became necessary to provide a small pumping installation for lifting purposes, which would entail the minimum amount of annual expenditure for up-keep and attendance.

An electric installation having been provided at Stowmarket for the lighting of that town, it was decided

that no better arrangement could be adopted than to utilise the surplus power there generated. The following is a brief description of the arrangement of pumps and motors :—

> The machinery is in duplicate, each set comprising a 3-throw pump driven by an elector-motor through worm-gearing running on ball bearings. The bearings of the motor are lubricated automatically, the worm and wheel running in an oil bath, so that no attention should be required other than to start the motors and stop them, when necessary. But even this labour has been dispensed with by the use of automatic switches, operated by floats controlled by the level of the sewage in the sump adjoining the pumping station. These switches can be adjusted so as to start either pump in advance of the other, and a convenient arrangement is to allow one pump to deal with the ordinary flow of sewage, the second pump remaining in reserve and only starting in the event of the first being unable to cope with any increased flow of sewage. As either pump can be made to start first, they can be worked alternately week by week, or month by month, as desired, so that both sets of machinery are kept in good working order and do an equal amount of work. In a pumping installation, which derives its power from an electric light plant, the current must be so drawn off as to cause no great fluctuation likely to appreciably affect the electric lights burning on the circuit; and for this purpose on the Coombs installation an arrangement consisting of a dash-pot with a multiple contact automatic switch has been used, by

which the starting current is gradually turned on, the movement occupying a period of from 5 to 10 seconds.

The absence of steam, gas, or oil engines in a pumping installation of this description enables the station to be kept scrupulously clean. The plant has now been working for nearly two years and has given considerable satisfaction.

At Cardiff, also, an Electrical Plant for pumping the sewage has been erected by the City Engineer, Mr. W. Harper, the power being drawn, as at Coombs, from an Electric Light Installation.

The motors and pumps are placed on a small chamber beneath the roadway, and the motors are directly connected with 3-inch centrifugal pumps with vertical spindles. Special bearings are fitted to the motors, so that the spindles run in a bath of oil and the thrust is taken by adjustable ball bearings.

The speed of the motors is about 1,300 revolutions per minute, and they are series wound and work on a 500-volt circuit.

The installation has given great satisfaction, and is economical and clean in working.

In selecting for any particular town any one of the systems described in this chapter, it must be remembered that financial considerations, though very important in a sewerage scheme, should take only a second place, the first desideratum being the efficient removal of the sewage. Of the various systems above described, the simplest and the least expensive is undoubtedly the "gravitation" system. Here the sewage flows to the outfall through conduits laid at gradients which should be self-cleansing. This is the

ideal system which every Sanitary Engineer desires to obtain, but unfortunately in most towns of any size it is impossible, and some kind of pumping has to be resorted to.

It is not necessary in all cases to have recourse to sectional pumping. In many schemes the sewage of a town can be gravitated to a single point and there lifted in one lift. This is often the next most economical system to that of simple gravitation.

In dealing with the various systems of sectional pumping, it is very difficult to say that either one or the other stands first in any exceptional manner. Circumstances vary so much in many places, and where in one position the Shone Hydro-Pneumatic System of drainage may be the most economical, a Hydraulic System may be the most expensive, and *vice versa.* There is no doubt in a general way that the first cost of Shone's Hydro-Pneumatic System as well as the expense of working it is cheaper than that of any hydraulic system. Lighter and smaller pipes and much less pressure is needed to work this system. The cost of water is greater than that of air, and although the water used in the hydraulic system is also used to flush the sewers, it takes up space in them, and allowance must be made for it. The Author has had considerable experience of the Shone System of Drainage and, excepting the few disadvantages mentioned earlier, it has always given satisfaction.

The Liernur System of drainage is not a system that appears to have found any approval with Engineers in the British Isles. Installations have been put up in some towns on the Continent, but in none is it said that the system has given much satisfaction. It is expensive, in-

asmuch as it necessitates two sets of sewers, one for fœcal matter and one for sullage in addition to separate pipes for disposal of stormwater. Expensive pneumatic plant is also necessary, and in a hot country it would, in the Author's opinion, be criminal to introduce a system that purposely allowed for putrefying house sewage to remain in the proximity of the houses for such a length of time as in this system.

In comparing the Shone's Hydro-Pneumatic System and the Liernur System, the following points are interesting:—

> The Liernur System takes only fœcal matter and very little liquid, while the Shone Hydro-Pneumatic System takes everything. The Shone Pneumatic System is automatic, while the Liernur necessitates skilled labour to work it.
>
> The placing of an iron receptacle holding several gallons of putrefying sewage at the bottom of the soil pipes close to each house is a distinct blot in the Liernur System.

CHAPTER II.

Sewers.—Having decided on the system to be adopted and the position of the outfall, the next information to be obtained is the population of the district or town to be sewered. The recent census, which has been taken all over India and which is admittedly the most complete yet made, lightens this task for the Sanitary Engineer and makes the work of calculating the present and prospective population a comparatively easy one. The mode usually adopted in approximating the future population is to ascertain what the past rate of increase has been for a cycle of years and to make the same, or, in some cases according to local circumstances, a greater allowance for the probable increase in the future. Population affects sewerage works inasmuch as each individual member of the community uses a certain amount of water and contributes a certain amount of solid matter to the sewers. The quantity of the water-supply of the city or town to be drained is the next factor to obtain. This information is generally not difficult to acquire, but the supply varies considerably in India, from the mofussil town with its well-supply of from 5 to 7 gallons per head per diem, to a city like Bombay with its lakes supplying 40 gallons per head per day. In the latter case the Engineer should allow 6 cubic feet of sewage per head per day, half to flow off in 8 hours. This rule, however, stands good only where a regular water-supply exists and not in villages or towns with tank and well-supplies.

Given the water-supply per head and the population, the capacity of the sewers can then easily be determined. If the population of a town is 10,000 and the water-supply is 20

gallons per head per diem, an allowance must be made for 200,000 gallons of sewage to be disposed of at the outfall per diem. But, owing to the fact that the largest amount of water is used in the early morning, one-half of the average supply should be taken to flow off in 8 hours, that is, the sewers should be capable of conveying 100,000 gallons in 8 hours, equal to 12,500 gallons in an hour, or 208 gallons per minute at the time of maximum flow.

The minimum velocity of sewage, usually held to be sufficient for satisfactory self-cleansing in England, may be taken as two feet per second, but it is usual to give a velocity greater than this, especially on small sewers up to 12 inches in diameter; but this has been found to be insufficient for India. The Author has, after considerable experience in Bombay, ascertained that it is, in this country, safer to fix the minimum at 3½ feet per second for all sewers, on account of the heavy nature of some of the foreign matters in the sewage. It must be carefully noted that the size of any sewer should be such that the volume of sewage delivered to it will result in a sufficient depth as to maintain the velocity given.

The formula used and published in tables and diagrams for use in designing sewers and water mains by Messrs. W. Santo Crimp and C. Ernest Bruges has been found to be reliable. It is invented by Messrs. Crimp and Bruges after experiments carried out on the London sewers. The results of the formula closely follow the results obtained from the well-known Kutter formula, which is, however, cumbersome and laborious to work out. By adjusting the co-efficient given in the formula, viz., 124, the results obtained may be made to correspond with Kutter's formula for different co-efficients of roughness. The co-efficient 124

corresponds with Kutter's N =·012. The formula may be confidently used in the design of drainage works in which stoneware pipes and brickwork of good quality are to be employed.

It is as follows :—

$$v = 124 \sqrt[3]{r^2} \sqrt{s}$$

Where v = Velocity in feet per second.
r = Hydraulic mean depth in feet.
s = Fall divided by the length.

For circular pipes running full or half-full, this is equivalent to $V = \dfrac{563 \sqrt[3]{D^2}}{\sqrt{I}}$, and $Q = \dfrac{3{\cdot}072 \sqrt[3]{D^8}}{\sqrt{I}}$

Where V = Velocity in feet per minute.
D = Diameter in inches = 48 r.
I = Inclination or the length divided by the fall = $\frac{1}{s}$.
Q = Cubic feet per minute delivered when running full.

The following example illustrates the working of the formula :—

Find, for example, the velocity and discharge of a 9-inch pipe sewer at a gradient of 1 in 200.

$$r = \frac{{\cdot}75}{4} = {\cdot}19 \text{ nearly.}$$

$$\therefore \quad \sqrt[3]{r^2} = {\cdot}3305.$$

$$\& \ v = 124 \times {\cdot}3305 \times \sqrt{\frac{1}{200}} = \frac{40{\cdot}98}{14{\cdot}14} = 2{\cdot}89 \text{ feet per}$$

second ; or thus

$$V = \frac{563 \sqrt[3]{81}}{\sqrt{200}} = 172 \text{ feet per minute.}$$

and $Q = {\cdot}4418 \times 172 = 76$ cub. feet per minute.

This result, as will be seen from the foregoing remarks, shows that the gradient is not sufficiently steep for a 9-inch pipe sewer.

In the same way with the above formulæ, the velocity and the discharge of any sewer can be calculated. As already stated there is a limit to the maximum velocity of flow in sewers, because of the solid matter in the sewage which tends to wear away the inside surface of the sewers. Several authorities, including Rankine and Rawlinson, limit this velocity to $4\frac{1}{2}$ feet per second which, in the opinion of the Author, is a low limit, but in deciding such a question the quality of the sewage to be dealt with must be considered. In Bombay the sewage contains a large quantity of road detritus derived from the basaltic rock with which all the roads are macadamised. In such sewage a maximum velocity of 5 feet per second should be given, but in ordinary domestic sewage 6 feet per second may be allowed without danger.

The modern practice in sewerage schemes is to use pipes and sewers of relatively much smaller diameters than those used in former years, and this more especially refers to pipe sewers. It has often been found with pipes laid years ago that they have never ordinarily carried more than 1/5th of their full capacity and it is manifestly more economical in such cases to use pipes of a smaller diameter. Other considerations, however, impose a limit on a minimum size and it is not advisable to lay any pipe sewer of a less diameter than 8 inches, even though calculations based on the formula already quoted might show that a pipe of much smaller capacity would do all the work required. The practice in Bombay in past years has been to lay pipe sewers of 9 inches in diameter as a minimum, but this is somewhat large.

Small sewers require a greater inclination than larger ones, and pipe sewers require less inclination than brick sewers.

For ready reference certain tables are here inserted, calculated from the formulæ already given.

Table I gives the value of $\sqrt[3]{r^2}$ for different values of "r" from ·01 to ·3.

Table II gives the areas in square feet of circular sewers and pipes, mostly used in sewerage works, and the value of $\sqrt[3]{r^2}$ when running full.

Table III gives the areas of the principal egg-shaped sewers in square feet and the value of $\sqrt[3]{r^2}$ when running full, two-thirds full and one-third full.

Table IV gives the gradients at which different sizes of pipe sewers should be laid to give different velocities, when running full or half-full.

Table V gives the gradients at which different sizes of ovoid sewers should be laid to give different velocities when running full.

TABLE I.

Giving the Value of $\sqrt[3]{r^2}$

r.	$\sqrt[3]{r^2}$	r.	$\sqrt[3]{r^2}$	r.	$\sqrt[3]{r^2}$	r.	$\sqrt[3]{r^2}$	r.	$\sqrt[3]{r^2}$	r.	$\sqrt[3]{r^2}$	r.	$\sqrt[3]{r^2}$	r.	$\sqrt[3]{r^2}$	r.	$\sqrt[3]{r^2}$	r.	$\sqrt[3]{r^2}$
		·30	·4481	·60	·7114	·90	·9322	1·20	1·129	1·50	1·310	1·80	1·480	2·10	1·640	2·40	1·793	2·70	1·939
·01	·0464	·31	·4580	·61	·7193	·91	·9391	1·21	1·136	1·51	1·316	1·81	1·485	2·11	1·645	2·41	1·798	2·71	1·944
·02	·0737	·32	·4678	·62	·7271	·92	·9459	1·22	1·142	1·52	1·322	1·82	1·491	2·12	1·650	2·42	1·803	2·72	1·949
·03	·0965	·33	·4775	·63	·7349	·93	·9528	1·23	1·148	1·53	1·328	1·83	1·496	2·13	1·656	2·43	1·808	2·73	1·953
·04	·1170	·34	·4871	·64	·7427	·94	·9596	1·24	1·154	1·54	1·334	1·84	1·502	2·14	1·661	2·44	1·813	2·74	1·958
·05	·1357	·35	·4966	·65	·7504	·95	·9664	1·25	1·160	1·55	1·339	1·85	1·507	2·15	1·666	2·45	1·818	2·75	1·963
·06	·1533	·36	·5061	·66	·7581	·96	·9732	1·26	1·167	1·56	1·345	1·86	1·513	2·16	1·671	2·46	1·822	2·76	1·968
·07	·1699	·37	·5154	·67	·7657	·97	·9799	1·27	1·173	1·57	1·351	1·87	1·518	2·17	1·676	2·47	1·827	2·77	1·973
·08	·1857	·38	·5246	·68	·7733	·98	·9866	1·28	1·179	1·58	1·357	1·88	1·523	2·18	1·681	2·48	1·832	2·78	1·977
·09	·2008	·39	·5338	·69	·7809	·99	·9933	1·29	1·185	1·59	1·362	1·89	1·529	2·19	1·686	2·49	1·837	2·79	1·982
·10	·2154	·40	·5429	·70	·7884	1·00	1·000	1·30	1·191	1·60	1·368	1·90	1·534	2·20	1·692	2·50	1·842	2·80	1·987
·11	·2296	·41	·5519	·71	·7959	1·01	1·007	1·31	1·197	1·61	1·374	1·91	1·540	2·21	1·697	2·51	1·847	2·81	1·991
·12	·2433	·42	·5608	·72	·8033	1·02	1·013	1·32	1·203	1·62	1·379	1·92	1·545	2·22	1·702	2·52	1·852	2·82	1·996
·13	·2566	·43	·5697	·73	·8107	1·03	1·020	1·33	1·210	1·63	1·385	1·93	1·550	2·23	1·707	2·53	1·857	2·83	2·001
·14	·2696	·44	·5785	·74	·8181	1·04	1·026	1·34	1·216	1·64	1·391	1·94	1·556	2·24	1·712	2·54	1·862	2·84	2·005
·15	·2823	·45	·5872	·75	·8255	1·05	1·033	1·35	1·222	1·65	1·396	1·95	1·561	2·25	1·717	2·55	1·867	2·85	2·010
·16	·2947	·46	·5959	·76	·8328	1·06	1·040	1·36	1·228	1·66	1·402	1·96	1·566	2·26	1·722	2·56	1·871	2·86	2·015
·17	·3069	·47	·6045	·77	·8401	1·07	1·046	1·37	1·234	1·67	1·408	1·97	1·572	2·27	1·727	2·57	1·876	2·87	2·019
·18	·3188	·48	·6130	·78	·8474	1·08	1·053	1·38	1·240	1·68	1·413	1·98	1·577	2·28	1·732	2·58	1·881	2·88	2·024
·19	·3305	·49	·6215	·79	·8546	1·09	1·059	1·39	1·246	1·69	1·419	1·99	1·582	2·29	1·737	2·59	1·886	2·89	2·029
·20	·3420	·50	·6300	·80	·8618	1·10	1·066	1·40	1·252	1·70	1·424	2·00	1·587	2·30	1·742	2·60	1·891	2·90	2·034
·21	·3533	·51	·6384	·81	·8690	1·11	1·072	1·41	1·257	1·71	1·430	2·01	1·593	2·31	1·748	2·61	1·896	2·91	2·038
·22	·3644	·52	·6467	·82	·8761	1·12	1·078	1·42	1·263	1·72	1·436	2·02	1·598	2·32	1·753	2·62	1·901	2·92	2·043
23	·3754	·53	·6550	·83	·8832	1·13	1·085	1·43	1·269	1·73	1·441	2·03	1·603	2·33	1·758	2·63	1·905	2·93	2·048
·24	·3862	·54	·6632	·84	·8903	1·14	1·091	1·44	1·275	1·74	1·447	2·04	1·609	2·34	1·763	2·64	1·910	2·94	2·052
·25	·3969	·55	·6714	·85	·8973	1·15	1·098	1·45	1·281	1·75	1·452	2·05	1·614	2·35	1·768	2·65	1·915	2·95	2·057
·26	·4074	·56	·6795	·86	·9043	1·16	1·104	1·46	1·287	1·76	1·458	2·06	1·619	2·36	1·773	2·66	1·920	2·96	2·062
·27	·4178	·57	·6875	·87	·9113	1·17	1·110	1·47	1·293	1·77	1·463	2·07	1·624	2·37	1·778	2·67	1·925	2·97	2·066
·28	·4280	·58	·6955	·88	·9183	1·18	1·117	1·48	1·299	1·78	1·469	2·08	1·630	2·38	1·783	2·68	1·929	2·98	2·071
·29	·4381	·59	·7035	·89	·9253	1·19	1·123	1·49	1·305	1·79	1·474	2·09	1·635	2·39	1·788	2·69	1·934	2·99	2·079
·30	·4481	·60	·7114	·90	·9322	1·20	1·129	1·50	1·310	1·80	1·480	2·10	1·640	2·40	1·793	2·70	1·939	3·00	2·080

TABLE II.

Areas of circular sewers and pipes in square feet and the value of $\sqrt[3]{r^2}$, when running full.

(*r = Hydraulic mean depth in feet.*)

Diameter in inches.	Area in square feet (full).	$\sqrt[3]{r^2}$
4	.0873	.1908
6	.1963	.2500
7	.2672	.2771
8	.3491	.3029
9	.4418	.3276
10	.5454	.3514
12	.7854	.3969
15	1.2272	.4605
18	1.7671	.5200
21	2.4053	.5763
24	3.1416	.6300
27	3.9761	.6814
30	4.9087	.7310
33	5.9396	.7790
36	7.0686	.8255

TABLE III.

Areas of egg-shaped sewers (old form) in square feet and the value of $\sqrt[3]{r^2}$

(r = *Hydraulic mean depth in feet.*)

Size.					Full.		Two-thirds full.		One-third full.	
Width.			Height.		Area in square feet	$\sqrt[3]{r^2}$	Area in square feet.	$\sqrt[3]{r^2}$	Area in square feet.	$\sqrt[3]{r^2}$
Ft.	In.		Ft.	In.						
1	8	×	2	6	3·1903	·6154	2·0994	·6518	·7889	·4912
2	0	×	3	0	4·5940	·6950	3·0232	·7360	1·1360	·5548
2	4	×	3	6	6·2529	·7702	4·1149	·8156	1·5462	·6147
2	6	×	3	9	7·1781	·8064	4·7237	·8540	1·7750	·6437
2	8	×	4	0	8·1671	·8419	5·3746	·8915	2·0195	·6720
3	0	×	4	6	10·337	·9107	6·8022	·9641	2·5560	·7269
3	4	×	5	0	12·761	·9770	8·3978	1·0346	3·1556	·7799
3	6	×	5	3	14·069	1·0092	9·2585	1·0688	3·4790	·8056
3	10	×	5	9	16·877	1·0734	11·106	1·1356	4·1732	·8560
4	0	×	6	0	18·376	1·1032	12·093	1·1683	4·5440	·8806
4	6	×	6	9	23·257	1·1933	15·305	1·2637	5·7510	·9526
4	8	×	7	0	25·012	1·2226	16·460	1·2948	6·1849	·9759
5	4	×	8	0	32·668	1·3365	21·498	1·4152	8·0782	1·0668
6	0	×	9	0	41·346	1·4457	27·209	1·5309	10·224	1·1540

TABLE IV.

Rates of inclination of circular sewers to give the following velocities, when running full or half-full.

Velocity in feet per second.	Diameter 4 in.	Diameter 6 in.	Diameter 7 in.	Diameter 8 in.	Diameter 9 in.	Diameter 10 in.	Diameter 12 in.	Diameter 15 in.	Diameter 18 in.	Diameter 21 in.	Diameter 24 in.	Diameter 27 in.	Diameter 30 in.
2	1 in 140	1 in 240	1 in 295	1 in 350	1 in 415	1 in 475	1 in 610	1 in 820	1 in 1050	1 in 1275	1 in 1525	1 in 1775	1 in 2050
2½	1 in 89	1 in 155	1 in 190	1 in 225	1 in 265	1 in 305	1 in 385	1 in 520	1 in 660	1 in 820	1 in 970	1 in 1138	1 in 1315
3	1 in 62	1 in 105	1 in 130	1 in 155	1 in 185	1 in 210	1 in 270	1 in 365	1 in 460	1 in 570	1 in 680	1 in 790	1 in 910
3½	1 in 46	1 in 78	1 in 96	1 in 115	1 in 135	1 in 155	1 in 200	1 in 265	1 in 340	1 in 415	1 in 500	1 in 585	1 in 670
4	1 in 35	1 in 60	1 in 73	1 in 88	1 in 105	1 in 120	1 in 150	1 in 205	1 in 260	1 in 320	1 in 380	1 in 445	1 in 515
4½	1 in 28	1 in 47	1 in 58	1 in 70	1 in 82	1 in 94	1 in 120	1 in 160	1 in 205	1 in 250	1 in 300	1 in 352	1 in 405
5	1 in 22	1 in 38	1 in 47	1 in 56	1 in 66	1 in 76	1 in 97	1 in 130	1 in 165	1 in 205	1 in 245	1 in 285	1 in 330
5½	1 in 19	1 in 32	1 in 39	1 in 47	1 in 55	1 in 63	1 in 80	1 in 105	1 in 138	1 in 170	1 in 200	1 in 234	1 in 270
6	1 in 16	1 in 27	1 in 33	1 in 39	1 in 46	1 in 53	1 in 67	1 in 91	1 in 115	1 in 140	1 in 170	1 in 197	1 in 230

TABLE V.

Rates of inclination of ovoid sewers (old form) to give the following velocities, when running full.

Velocity in feet per second.	2′—0″ × 3′—0″	2′—6″ × 3′—9″	2′—8″ × 4′—0″	3′—0″ × 4′—6″	3′—4″ × 5′—0″	3′—10″ × 5′—9″	4′—0″ × 6′—0″	4′—8″ × 7′—0″	5′—4″ × 8′—0″
2	1 in 1850	1 in 2500	1 in 2725	1 in 3200	1 in 3650	1 in 4400	1 in 4700	1 in 5800	1 in 6890
$2\frac{1}{2}$	1 in 1200	1 in 1600	1 in 1750	1 in 2050	1 in 2350	1 in 2825	1 in 3000	1 in 3700	1 in 4400
3	1 in 825	1 in 1100	1 in 1200	1 in 1400	1 in 1634	1 in 1950	1 in 2075	1 in 2550	1 in 3050
$3\frac{1}{2}$	1 in 600	1 in 815	1 in 900	1 in 1050	1 in 1200	1 in 1450	1 in 1525	1 in 1875	1 in 2250
4	1 in 460	1 in 625	1 in 685	1 in 800	1 in 900	1 in 1100	1 in 1175	1 in 1440	1 in 1700
$4\frac{1}{2}$	1 in 355	1 in 500	1 in 538	1 in 630	1 in 725	1 in 875	1 in 925	1 in 1130	1 in 1350
5	1 in 300	1 in 400	1 in 435	1 in 500	1 in 590	1 in 700	1 in 750	1 in 910	1 in 1100

MATERIALS.

The materials other than metals, such as iron and steel, used in the construction of sewerage works are cement, lime, sand, mortar, concrete, bricks, stone and pipes.

Cement.—The best known natural cement is Roman cement, which is made from a stone found in form of nodules in the island of Sheppey, and elsewhere in the geological formation known as "London Clay." This cement was first discovered by a Mr. Parker in the year 1796, and usually contains 55 parts of lime, 38 of clay, and 7 of iron. In Russia, America, India and elsewhere, similar natural cements have been met with, but they are comparatively rare. This rareness necessitated the making of an artificial cement and we are much indebted to a General Paisley for one of our best and earliest artificial cements. It was he who first proved that an artificial cement could be made equal to that obtained from natural sources, and he prepared it from a mixture of chalk and blue alluvial clay, the proportion being four parts by weight of chalk and 5.5 parts of clay.

The principal cement used in sanitary works is that known as Portland cement. Portland cement is so named simply because of its similarity in colour to Portland stone but has no connection with it in any other way. It is usually manufactured on the banks of the Rivers Thames and Medway, from a mixture of chalk and mud obtained from the beds of those rivers. Other materials are also employed in its manufacture such as blue lias limestone and shale. There are many makers and many brands of this class of cement, but in all a mixture of clay and lime after calcination in the proportion of not less than 35 per cent. of clay and

not more than 61 per cent. of lime is necessary. If there is too large a percentage of clay, the cement is very quick-setting, and never attains the strength of a more slow-setting cement. A slight excess of lime enables the materials to burn at a high temperature thus making a slow-setting and strong cement. In all cements, fineness is a great feature, and a good cement should pass 90 per cent. of its bulk through a sieve containing 5,800 meshes per square inch.

The composition of a thoroughly good Portland cement is :—

Alumina and Oxide of Iron	12 %
Silica	23 %
Lime	61 %
Magnesia	1 %
Sulphuric Acid	1·5 %
Carbonic acid and moisture	1·5 %
Total	100

Portland cement should always be tested before it is used and considerable variations will be met with even in the best brand. For sewerage works only the best quality should be used. The most important test for cement is that of tensile strength and for making this test small quantities should be taken from a number of casks. The samples taken should then be made into briquettes one square inch in section at the centre and immersed in water after seven hours, care being taken that there be no disturbance of the water after the briquettes are immersed. The briquettes should remain in water for periods varying from 3 to 30 days.

Those immersed for three days should stand without fracture a tensile strain of at least 300lbs. per square inch,

those immersed for seven days at least 400 lbs. per square inch, while those immersed for a month not less than 550 lbs. per square inch.

Another test is the sand test. Briquettes made in the proportion of three of absolutely clean sharp sand and one of cement should be left standing one day in the mould and twenty-seven days in water; they should then bear not less than 200 lbs. of tensile strain per square inch, and any less strain would betoken a doubtful cement. Many Engineers prefer this test to the former one, as pure cement is not extensively used.

Rapidity of setting may be judged by the use of a machine known as Vicat's Needle. A pad of cement should not be so set in less than one hour that the needle cannot penetrate it.

The specific gravity of Portland cement, one month after manufacture, should not be less than 3·1.

Before being used cement should, as a rule, be cooled by spreading it on a floor in a dry room. This also allows the free lime which exists in all new cement to slake; if this is not done, there is a likelihood of its "blowing" after the work has set.

Only just so much of the cement as is required for immediate use should be mixed at one time, as once it has commenced to harden it cannot be worked up again. The amount of water desirable to be used in mixing cement varies with different makes, but it should usually be 20 per cent. of the volume of dry material.

Portland cement is the only cement that should be used for works that may come in contact with sewage, as it is practically unaffected by the acids, should such exist, in the sewage. Cement, said to be similar to Portland

cement, is now being made in Madras and Calcutta, but the Author has had no experience of it and can therefore say nothing as to its quality.

Sand.—Sand used should be sharp and clean and entirely free from loam or any organic matter. The sand principally used in Bombay is basaltic sand, washed from neighbouring hills of volcanic formation during the monsoon months. The use of sea sand is undesirable with lime, at any rate until thoroughly washed in fresh water, because of its liability to sweat in a humid atmosphere, but with cement slight salinity makes no difference.

Lime.—Lime may be divided into two classes :—

I. (*a*) Fat or common lime, which gains no consistency under water, being only pure chalk without any adultrance.

(*b*) Non-hydraulic lime, which is a combination of lime and non-soluble mineral matter, such as silica and alumina.

II. Hydraulic lime, which is obtained from limestones having a greater or less percentage of soluble silica and alumina.

Fat lime is a rich lime and is found in India, principally in Madras, and contains an excessive quantity of carbonate of lime. It can be usefully employed in whitewashing, plastering and stucco work as it takes a good polish.

Non-hydraulic lime is a lime deficient in soluble silica and alumina and requires the addition of pumice to give it hydraulic properties. Most of the pumice used in India is obtained from Aden and is a volcanic product.

Probably the best known hydraulic lime in India is found in the form of kankar. Kankar is obtained either

in nodules on or near the surface of the ground or is dug up from pits in large lumps in alluvial soil. Kankar is a species of sub-soil tufa formed by the deposition of calcareous matter extracted from beds of sand and clay in minute quantities and re-deposited in the form of kankar. A good kankar should give the following proportions :—

Carbonate of lime....................	112 grs.
Clay..	9 ,,
Sand...	29 ,,
Total ...	150 grs.

An easy test for determining the quality of kankar is to take and pound 150 grains, so that it will pass through a fine sieve. Add sufficient hydrochloric acid until effervesence ceases and filter carefully through blotting paper. That which remains is clay or sand, or both. The difference between this weight and the 150 grains represents the carbonate of lime, dissolved by the hydrochloric acid. The remainder should be now washed by decantation so as to get rid of the lighter particles of clay until the sand is left, which should be dried and weighed. The difference gives the proportion of clay and sand.

In purchasing lime it should be remembered that the addition of 10% of water will give a 30% increase in measurement—a fact which should not be overlooked in taking over lime for works.

Mortar.—The proportions of sand and cement are usually from two to three of sand to one of cement, measured dry. Cement mortar for jointing pipes should be in the proportion of one part of cement to one part of sand. Such cement and sand should be mixed dry before water is added, and care should be taken that water in

excess is not used. Sand should be screened and only the finer portion used in cement mortar. Cement mortar should never be ground.

In lime mortar, the best proportion for Indian lime of good quality is two parts (by measure, dry) of lime and three of sand. For hydraulic works and foundations, equal parts of lime and sand should be used, and in the case of lime being non-hydraulic, the mixture for mortar should be one part lime, one part surki, and one part sand (surki being bricks pounded very finely). As a rule, kankar should not have surki mixed with it; such a mixture gives a weakened mortar. It is not easy to lay down a hard-and-fast line for the properties of lime-mortar and every Engineer should make experiments for himself with the lime of his district. The ingredients for mortar should be well mixed, the lime being previously screened to remove extraneous unburnt matter, and then wetted and ground in a mill, ghanni, or mixing machine, and in the case of a single ghanni being used, it should usually be subjected to at least 160 full rounds of the ghanni stone, or as many rounds as experience may show to be necessary. A ghanni is a simple form of mill and consists of a circular channel, usually 30 feet in diameter, 1 foot 4 inches wide, and about 1 foot deep, lined at the bottom and sides with flag stones set dry. In the centre is a short vertical post, round which revolves a horizontal bar, to the outer end of which a bullock is yoked. A grinding stone, some 2 feet 6 inches in diameter and 1 foot in thickness, is attached to the bar and is worked round in the channel by the bullock. A ghanni may have two grinding stones attached to two horizontal bars in directly opposite directions from the central post.

Hydraulic lime mortar should be mixed four parts (by measure, dry) of lime, and four of sand and wetted and ground in a ghanni in the same way as common mortar.

Concrete.—The ingredients for concrete are ballast or gravel, sand, and a cementing material, either Portland cement or lime. When good sharp river ballast can be obtained, it will frequently be found to contain sufficient sand mixed with the stones to be ready for use, but as this is not always obtainable, broken stones or shingle have to be utilized and sand added to the whole and well mixed. Finer particles of stone are better than sand, if they can be obtained in a sufficient quantity. For cement concrete a good proportion to adopt is for the matrix two parts broken stone, two parts shingle, and two parts sand. The materials can be mixed together and the volume ascertained and then an amount of cement added, which will bring the volume of matrix to cement 4 to 1, 5 to 1, 6 to 1, and so on, according to strength and quality of concrete required. 6 to 1 will make a good quality concrete for ordinary purposes. Cement concrete is much stronger by having stones in it of various sizes from the maximum downwards. The concrete should be mixed on a stage constructed of planks or boards, the materials forming the aggregate being, if necessary, previously washed. The whole mass should be turned over at least twice dry, and three times after wetting, so as to become thoroughly intermixed. Water should not be splashed on from a bucket but carefully added from a large watering pot or hose fitted with a big rose, as this will facilitate the whole mass being equally wetted. In England it is becoming very general, where large masses of concrete are required, to perform the mixing in a concrete mixer. This consists

of a revolving drum provided with a large manhole door. To fill the mixer, the drum is revolved until the manhole door is on the top of the drum. A definite volume of matrix is then put in, together with an ascertained quantity of water and then the proper proportion of cement is added. The manhole cover is then clipped on and the drum revolved. The manhole is finally opened when at the bottom and the concrete automatically discharges into carts or trucks. By these means absolute control is obtained over the process, and it has been found that an equally strong concrete can be produced with a smaller proportion of cement than by hand mixing. In putting concrete in position, Engineers differ considerably as to the best thickness for each layer and the amount of consolidation, but the Author has found that in India for ordinary purposes, if the concrete is deposited in layers of one foot and rammed or punned until the cement just begins to form a cream on the surface, it sets in a perfectly solid homogenous mass. If the concrete, however, is to bear a heavy weight, a less thickness of layers is desirable. The surface of one layer should be thoroughly well wetted and set before adding a second layer, and if any considerable period has elapsed since the first was put down it should be picked over to ensure a good joint. There is probably no work which requires such careful supervision as the mixing and putting in position of concrete. The materials must be thoroughly clean, and when the correctly measured amount of cement has been added, the mass must be thoroughly well turned over, the proper portion of water added, and finally the concrete must be sufficiently, but not excessively, rammed when in position. All this can only be ensured by careful and constant supervision. It should be noted that 125

cubic feet of dry materials will form 100 cubic feet of concrete solid.

A rough and ready method of gauging the best proportions of broken stone and sand for good concrete, and one which can be adopted by any one without difficulty, is as follows :—

An ordinary bucket should be filled with broken stone, level with the top, and as much water poured in as the bucket will hold. This quantity of water represents the whole of the space between the interstices in the stones and when poured off and measured will give the proper portion of sand to be added. The sand can then be added and the bucket refilled in the same way and the water again occupying the interstices will represent the minimum amount of cement to be used. In actual practice it is advisable to keep the quantity of cement somewhat in excess of the amount gauged by this method, so as to ensure every particle of the aggregate being thoroughly cemented together. This method should be employed only so far as the stone and sand are concerned, as the former varies in size in different localities, and even if broken by hand is not always uniform. The proportion of cement should be fixed in accordance with the nature of the work and quality of concrete required. The quantity as ascertained by the method described, however, should under no circumstances be reduced, as the concrete will not otherwise be uniform or properly cemented together.

Stone for concrete should be broken to a size not larger than would pass through a 2-inch ring.

Common lime concrete should be made of one part of lime mortar and two parts of broken stone.

Hydraulic lime concrete should be made of three parts of mortar, four parts of shingle, and four parts of broken stone.

When concrete is being laid in such a position that it is to be more than two feet in thickness it is admissible to allow rubble stones not exceeding one-half a cubic foot in size to be inserted in the concrete, but in such cases no stone should be laid nearer than nine inches from any other in any direction, nor nearer than nine inches from the surface.

Bricks.—Bricks are made of tempered clay, formed in moulds to the requisite size and shape and then burnt in a kiln. The outsides of bricks made of clay deposited with salt show dampness in humid atmosphere and require to be painted. All bricks for sanitary purposes should be made of the best quality procurable and of uniform colour with a hard impervious surface. A simple test for hardness is that a finger nail should not be able to make a scratch or mark on the surface. The principal test for bricks is that of absorption and Engineers generally lay down that a brick of good quality should not absorb more than 10 % of its dry weight after 24 hours' immersion in water. Another test known as the crushing test is that a brick should resist the weight of 500 lbs. per square inch. All bricks should ring well when struck, be table-moulded, sound, hard, regular, well burnt and with straight sharp arrises, and should not vary from the standard size.

Stone.—Building stone is classed under three heads, silicious, argillageous, and calcareous.

Stone is rarely used in sewerage works and the Sanitary Engineer may have little occasion to deal with this material,

except for pumping stations and other buildings ; but if it is found necessary to use this material, then care must be taken that none with vents or flaws or traversed with seams of perishable material should be used.

The principal kinds used in Bombay are basaltic trap or blue stone, Kurla yellow trap, both being silicious stones, and a light coloured building calcareous stone known as Porebundar stone. Any of these are suitable for building ; but basaltic trap is the best. The absorption of basaltic trap is very small being ·30 per cent. of its dry weight, while that of Kurla yellow trap is as much as 4 per cent.

Pipes.—Stoneware pipes of a greater diameter than 18 inches are rarely used. Pipes exceeding this size are difficult to construct of good shape and are consequently expensive. In England pipes varying from 18 to 36 inches in diameter are made of concrete, and are now largely used. The concrete pipes have not the strength of stoneware pipes and it is necessary in every case to surround them with concrete, a minimum of 4 inches beyond the outside of the tube being generally considered sufficient. The concrete is usually made with granite chippings and cement, so that great hardness is procured.

The advantages of the concrete tubes are, that they can be made absolutely circular and straight, and they are useful where the size of the sewer is too large for stoneware and too small for brick sewers.

The pipes mostly used in connection with pipe sewers are of two kinds, *viz.*, stoneware and fire clay. Cast iron, though probably the best class of conduit for sewage, is too expensive, except under special circumstances. Of the two classes of earthenware pipes, stoneware is usually specified by Engineers, fire clay pipes being thickness for thickness

not nearly so strong and durable as stoneware. They also have usually large absorption power, which is fatal to their use. The thickness of stoneware pipes should be at least $^1/_{12}$ of their diameter, and practice shows that the following table is reliable :—

Internal diameter.	Thickness of material.
3 inches.	⅜ inch.
4 "	½ "
6 "	⅝ "
9 "	¾ "
12 "	1 "
15 "	1¼ "
18 "	1½ "

The depth of the socket should not be less than 1½ inches for all pipes under 9 inches in diameter, 2 inches for 9 inches and 12-inch pipes, and 2½ inches for all sizes over 12 inches. The internal diameter of the socket should be sufficiently large to allow a joint of ¼ inch all round the outside of the pipe intended to enter it so that a caulking of tarred gasket may be inserted.

The qualifications of a good pipe are that it should be perfectly straight, truly cylindrical, thoroughly salt, glazed and burnt, and free from cracks, flaws, and defects of every description. Every pipe should be finished with a perfectly smooth interior.

The only test short of chemical analysis for a stoneware pipe as opposed to a fire clay one, is that of absorption. A piece of good stoneware pipe should absorb only 2 per cent. of its own dry weight, after 48 hours' immersion in water. A fire clay pipe will absorb from 7 to 10 per cent. of its own dry weight. Such a pipe, sooner or later, must fail on account of the action of sewage on the clay.

The tests which the Author usually lays down for stoneware pipes are :—

(1) That a piece about 2 inches square from any part of the pipe shall not absorb after 48 hours' immersion in water more than 2 per cent. of its own dry weight of water.

(2) That the pipe shall be capable of resisting a bursting pressure of 30 lbs. per square inch.

(3) That the breaking weight of the pipe shall not be less than 1 ton applied by means of a lever or otherwise to the centre of a thick flat board of hard wood, of the same length as the pipe, laid along the top of the pipe throughout its length exclusive of the socket. The pipe, when subjected to this test, should be laid on a similar flat board, the socket overhanging, a layer of felt being laid between the pipe and the boards.

CONSTRUCTION.

It is most necessary that sewers should be laid straight and true with a regular and uniform gradient. Too much importance cannot be attached to this for, once the sewer is laid and the trench filled in, it is lost to view and inequalities in gradients are not easily detected. The proper laying of the sewer can only be ensured by the use of sight rails and boning rods. Sight rails consist of two uprights fixed on either side of the trench, with a straight cross rail attached to them horizontally. They are placed at convenient distances along the line of the sewer, and the levels of the cross rails are so fixed that their upper edges are on a plane parallel to the gradient of the sewer, and at a constant height from its bed. If the boning rod (the head

of which is like a T square) of a length equal to the above height is moved along the line of sight between the two sight rails, the lower end determines the level of the invert of the sewer. Three sight rails rather than two should be used for one stretch of a sewer, and they should be constantly checked to see that they have not settled or have been moved. In laying pipes care should be taken that they are laid on an even bearing, for, if laid on a point of rock, sooner or later they will fracture and possibly subside, and at any rate will allow sewage to soak away into the soil. If laid on a rocky foundation it is advisable to bed the pipes on an even cushion of 2 inches or so of muram.

In drainage contracts it will be found satisfactory where ground is of uncertain quality, to lay down in the specification that the width of the trench which will be measured for 9-inch pipe sewers shall be 3 feet. A general rule may, however, be adopted that all trenches shall be at least 2 feet wider than the greatest diameter of the pipe.

The sides of the trench should be carefully secured and shored, when the excavation requires to be carried down to a great depth. No hard-and-fast rule can be laid down for the maximum depth to which the excavation should be carried without the trench being shored, which entirely depends on the character of the soil met with, and on the latter also depends the kind of shoring to be adopted. In reclaimed ground, it will be found dangerous to excavate deeper than three or four feet without shoring; while in good muram, a trench can be dug to a depth of seven or eight feet without any necessity for protection against collapse. Subsoil water also governs this question. A dry soil which will stand without shoring will require, if there is subsoil water running into the trench, to be shored. Of all

METHODS OF SHORING TRENCHES.

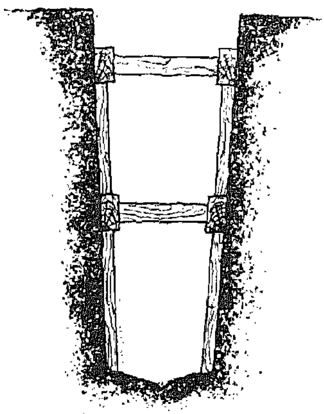


FIG. 5.

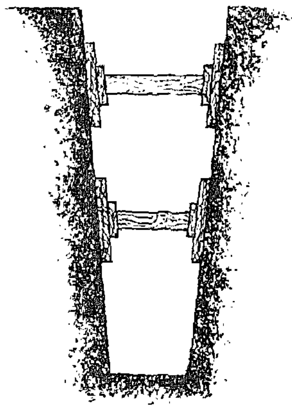


FIG. 6.

METHOD OF SHORING IN BAD GROUND.

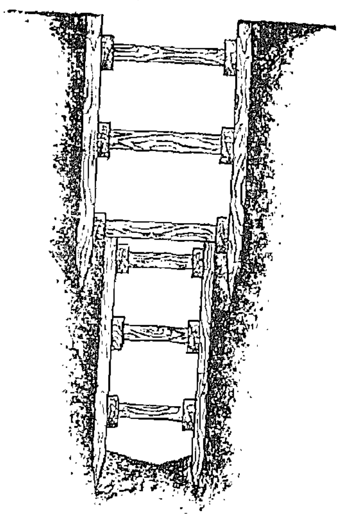


FIG. 7.

excavations, the worst and the most difficult is that of running sand. When excavations exceed a depth of 16 feet or so, it may be found cheaper in good ground to tunnel or in other words to run a heading. Three principal kinds of shoring may be adopted, and are shown in Figs. 5, 6, and 7.

In Fig. 5 the shoring is of the simplest kind. The timbering in this case, if it slips at all, must tighten up against the side of the trench, the excavation being wider at the top than at the bottom. The walings W are kept in position by struts S and props B are in some cases added. In instances where it is desired to support a large surface of ground poling boards P are put in as in Fig. 6. In bad ground close shoring as in Fig. 7 is necessary and the poling boards are used as runners. In such shoring the struts should be of as great a diameter as possible, for, if small, they have a tendency to split the walings; the distances between them vertically should be about 5 feet.

It is necessary for the proper and efficient execution of sewerage works that the trenches or excavations should be quite dry, and pumping must therefore be employed wherever water is met with. No masonry should be built, no concrete deposited, and no pipe joints made in water. The water must be kept down by the pumps to below the level of any work and pumping continued until and as long as may be necessary for the cement to have set hard.

If the bottom of the trench is soft and muddy it is unsuitable for sewerage works without additional foundation being provided to carry the pipe or sewer. The best expedient to be adopted in such cases is to cause dry rubble to be rammed in the bottom of the trenches as deep as possible, and on this bedding of stones the sewer should be laid or constructed with a layer of good muram or concrete between.

Fig. 8 shews the section of an ovoid or egg-shaped sewer 2 feet 6 inches by 3 feet 9 inches. The invert of the sewer is formed of blocks of cement concrete carefully and properly moulded in boxes to the form and dimensions required. The concrete for the blocks is composed by measure in the following proportions, *viz.*, one part of cement, two parts of sand, and two parts of clean river shingle. The concrete, as soon as mixed, is filled into the mould boxes and well rammed. The blocks should remain in the moulds for two days and be kept well moistened with water. They are then taken out and kept in the shade for two or more days before they are used in the work. The blocks should be laid as close together as possible and the joints should be filled in with neat cement mixed to the consistency of cream.

The excavation for an ovoid sewer between the invert and the springing line should, whenever possible, be taken down, not vertically, but in the shape of the sewer. The walls of the ovoid sewer between the invert and the springing line are constructed of cement concrete deposited and well rammed between the sides of the trench shaped as above described, and a centering formed to the true internal shape of the sewer after allowing for half an inch for a facing of cement plaster. After the concrete is set, and the centering removed, the internal face is rendered with cement and sand mixed one to one. The covering arch is also formed of cement concrete, rammed *in situ* and plastered on the inside with cement.

In the new form of ovoid sewer, the vertical height is one and-a-half times the transverse diameter, *i.e.*, three times the radius of the covering arch. The invert is struck from a centre on the vertical height with a radius equal to

SECTION OF OVOID-SEWER 2′-6″ × 3′-9″

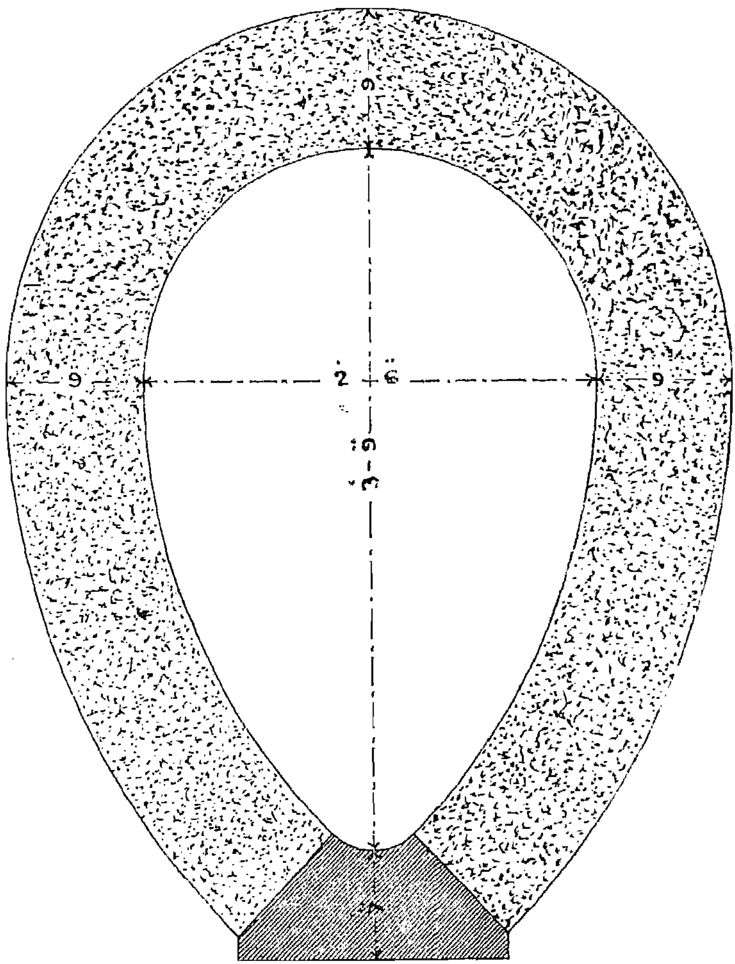


FIG. 8.

one-eighth of the transverse diameter, and the sides are struck from centres on the prolongations of the transverse diameter with a radius equal to one and a third times the length of that diameter ; while in the old form of ovoid sewer, the radius of the invert is one-fourth of the transverse diameter and that of the sides one and a half times the transverse diameter.

Another not unusual construction for ovoid sewers is that of double brickwork set and rendered in cement as shown in Fig. 9. In this class of sewer, concrete blocks are also advisable for the invert. A simple formula for ascertaining the thickness of brickwork required is :—

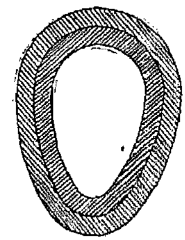


FIG 9

d=depth of excavation in feet,

r=the external radius of the sewer in feet,

then the thickness of the brickwork in feet is $\frac{d\,r}{100}$.

An allowance of 50 per cent. should be made on the results of this formula for Indian made bricks, because such bricks are much inferior to English, both in shape and quality. For this reason cement plastering, both on the inside and the outside of sewers built with Indian bricks, is necessary to finish the sewer off with an even face, unless concrete is used as a cover or hood, and then cement plastering only on the inside is required. With English bricks only pointing of the inside face is necessary. With ovoid sewers built with Indian bricks of a size 2 feet 6 inches by 3 feet 9 inches in solid ground not exceeding 20 feet in depth, the thickness of the sewer should be two bricks thick, or one brick with a hood of 6 inches of lime concrete. For sewers not exceeding 4 feet in diameter the thickness should be two bricks thick with a cover of 6 inches of lime concrete, the thickness of the brickwork increasing proportionately to the size of the sewer.

Fig. 10 shows an ovoid sewer only one brick thick enclosed entirely with concrete. This type is useful in indifferent ground and at considerable depths.

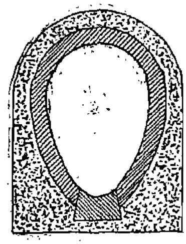


FIG 10

In some sewers constructed of concrete the arch is formed of concrete voussoirs, as shown in Fig. 11. The voussoirs are made in moulds in the same way as the blocks described in regard to Fig. 8. This is a

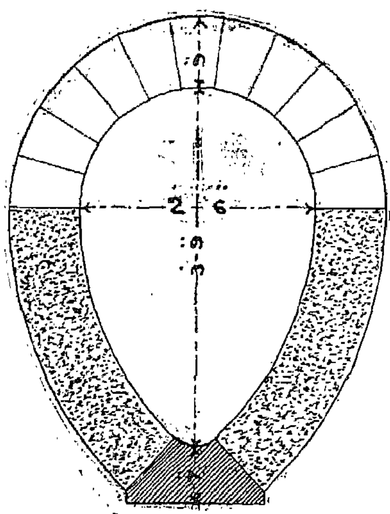


FIG 11

useful construction of sewer and is recommended in bad ground on account of its strength.

Fig. 12 shows another type of ovoid sewer known as the new egg-shaped and is for use in gravel or running sand. The invert blocks may be of concrete or stoneware. It will be noticed here that the lower half of this sewer is well protected with a covering of cement concrete.

In recent years circular brick sewers have found greater favour among Engineers than ovoid or egg-shaped. There are several reasons for this, the principal being that circular sewers of a large size are rarely called upon to deal with so little sewage, as to make an egg-shaped sewer of similar capacity advantageous. Again, the length of the wetted perimeter of a circular sewer is with equal volumes of sewage less than that of an egg-shaped sewer; circular sewers are also usually more economical in construction.

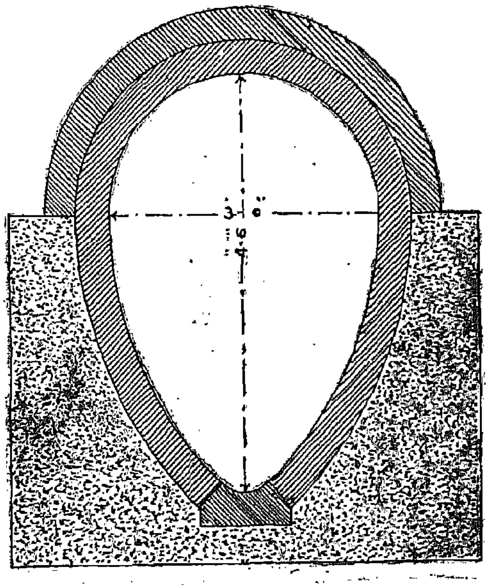


FIG 12

Stoneware junction blocks, of the shape shown in Fig. 13, are inserted in the wall of the sewers above springing level, wherever required, for connections of house drains.

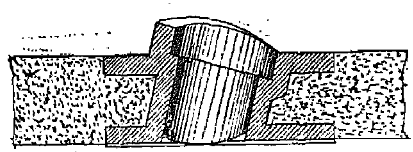


FIG 13

Plate 6 shows a design for manholes for ovoid sewers. They are built of brickwork set in cement or hydraulic mortar, and rendered both internally and externally

with cement plaster. Cast-iron steps are inserted in the manhole, as the brickwork proceeds, to enable workmen to go down into the sewer when required, with a notch in the wall in lieu of the last step, as any projection at this level would be liable to catch rags, etc., and cause obstruction to the flow of sewage. In certain manholes a groove is left in the invert and walls for flushing purposes as shewn in Plate 6. Into this groove a wooden door is let down and kept there until sufficient sewage is dammed up to give a good flush. The manholes are covered with cast iron frames and covers hereinafter described.

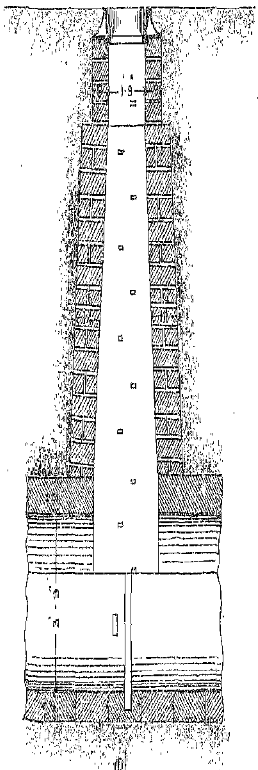
Pipe Sewer Laying.—In the laying of pipe sewers, the pipes should be first laid and fitted dry previous to the jointing being commenced, such junctions being inserted as may be required for house drainage connections. They should then be plumbed and boned to ensure their being truly laid both to line and gradient. A gasket of hemp, prepared in one length for each length, and tarred ready for use before being brought on the work, is then inserted into each joint, completely passing once round the spigot end of the pipe, and driven well home to the base of the socket, care being taken that not more than a quarter of the depth of the socket is taken up. Portland cement mortar is then forced into the joint until the whole space round the spigot between it and the socket is quite full, and the joint is then finished off with a neat splayed fillet. When there is any water in the trench the joint should be protected by means of a piece of cloth tied around it.

Patent Joint Pipes.—There are many patent joints for stoneware pipes in the market and under certain conditions some serve a very useful purpose, but they are naturally

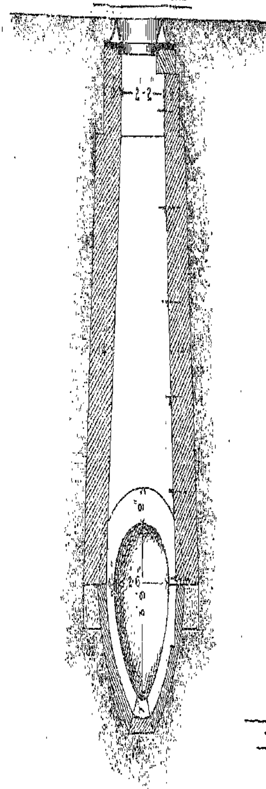
— DETAILS OF MANHOLES ON OVOID SEWER —

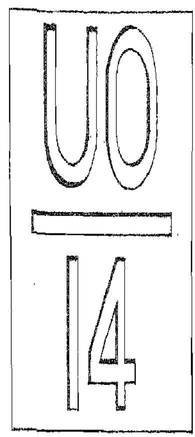
— SCALE 4 FEET TO AN INCH —

— SECTION AT A.A —

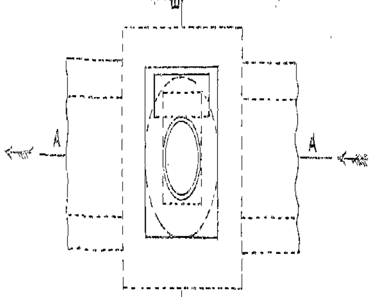


— SECTION AT B.B. —





— DETAILS OF STONE TO INDICATE —
— THE NUMBER OF MANHOLES —



— PLAN —

IMPROVED STANFORD JOINT

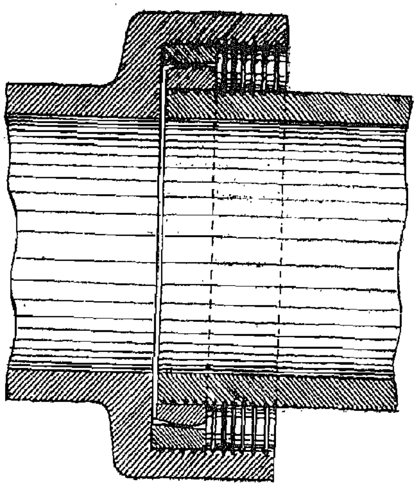


FIG. 14.

BUTTON'S PATENT JOINT.

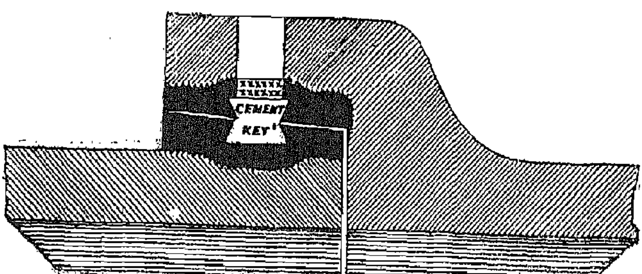
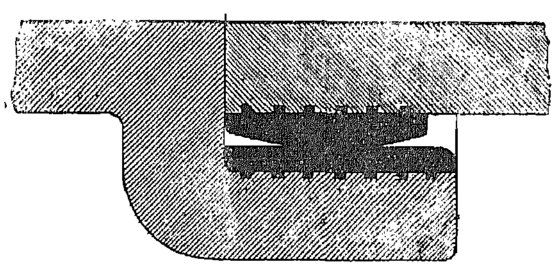


FIG. 15.

considerably more expensive than ordinary stoneware pipes.

The Stanford Joint, as shewn in Fig. 14, is similar in construction to the turned spigot and faucet joints of cast iron pipes, being formed of turned rings of a durable material generally consisting of a composition of sulphur, tar, and ground earthenware. These rings which are spherically shaped exactly fit into each other being counterparts and, in order to allow of some play, the sockets are slightly concave and the spigots slightly convex. The complete joint is made by grooving the rings and it is claimed that a perfect joint is made thereby.

Button's Patent Secure Joint, Fig 15.—In this joint a bituminous material is cast on to the spigot and the faucet. In this material grooves are formed so that when the pipe is driven home in the socket an annular groove or space is formed ; liquid cement is then run in through a hole in the pipe socket until a complete key of cement is formed and the joint made water-tight.

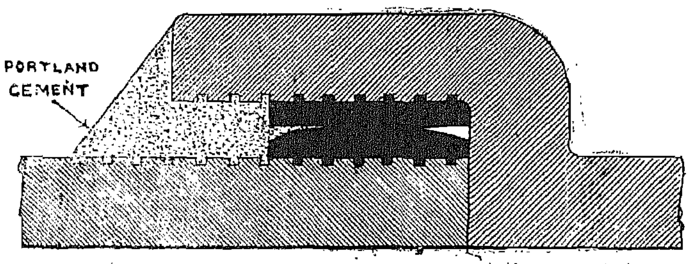


SECTION OF SELF=ADJUSTING JOINT.

FIG. 16

Doulton & Co. have a patent self-adjusting pipe (Fig. 16) for which it is claimed that no cement is required

for jointing purposes and the grooves are merely greased or tarred. The pattern, shewn in Fig. 17, is, however, also



SECTION OF COMPOSITE JOINT

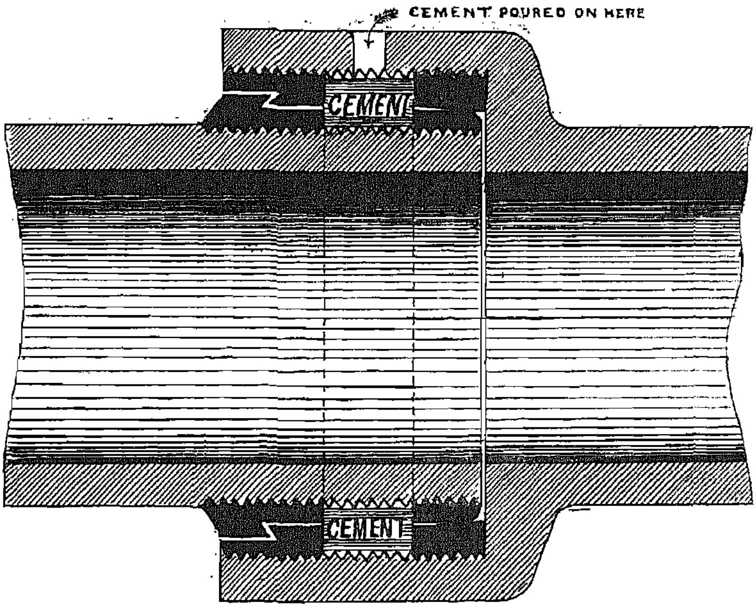
FIG. 17.

manufactured for those who prefer to have a more certain joint.

The Hassall Improved Patent Safety Joint, shewn in Fig. 18, is a favourite and largely used. As in the Button joint, rings are cast on with the idea of centering the pipes and retaining them in position, while the operation of running Portland cement is being effected. Plastic is applied to the end of the spigot and between the surfaces of the bituminous rings, so as to have a cushion to embed them and render harmless any grit that may have got there and to prevent the cement from running into the pipe. The groove is filled with Portland cement. This is a good joint and has successfully stood the test for several years. Many pipe makers in England hold a license to manufacture joints on this principle.

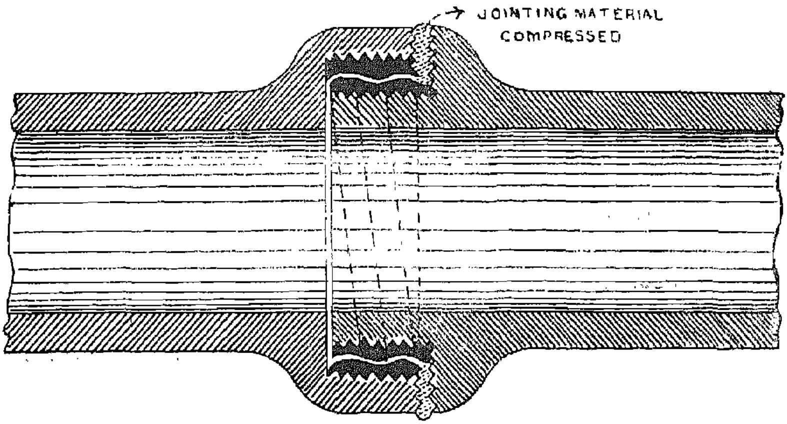
Fig. 19 shews a drawing of Sykes Patent Joints. On the spigot and the socket of each pipe are formed in bituminous composition a male and a female screw in such a manner as to give a little play in adjusting the joint, so as to secure flexibility without interfering with the proper level of the pipe when laid. The spigot is also provided with a strong collar or ring, against which when jointing

HASSALL'S PATENT JOINT.

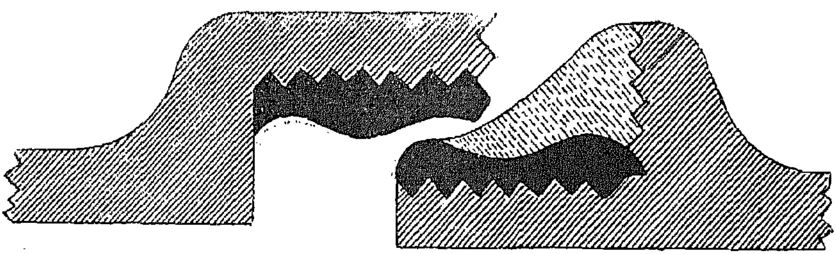


SECTION.

FIG. 18.



BEFORE JOINTING.



AFTER JOINTING.

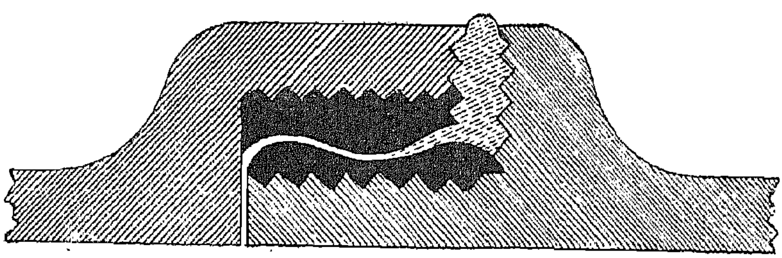


FIG. 19.

the pipes, a fillet of cement composition is placed which is compressed between the end of the socket and the rim by the act of screwing the pipes together. The pressure forces the superfluous cement composition into the space left for play in the thread. It is claimed that these joints have stood a hydraulic test of 140 lbs. per square inch without leaking. These pipes are made by the Albion Clay Co.

The Sutton Patent Joint Pipe, (Fig. 20), is a joint in many ways similar to the Hassall, but is said to be a slight improvement on it. In this joint also Plastic is used, but the liquid cement is pumped in through one

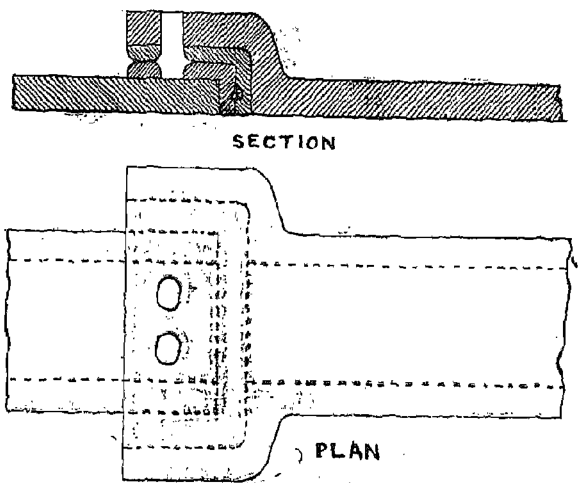


FIG 20

of the two openings in the socket of the pipe by means of a simple and cheap hand pump, until it appears through the other opening, when the joint may be considered to be successfully made.

These pipes have been used with success in Bombay in positions, where it would have been impossible to make any ordinary joint with safety, owing to running water in the trench. Pipe-layers in India are very conservative and have at first a strong objection to these patent joints, but after a little practice they are able to make two joints of patent pipes in the time they would require to complete one ordinary joint.

In all positions where trenches are water-logged, and it is impossible to keep them free of water, it is better for the Engineer to spend the extra money in using good special joint pipes and to be sure of good water-tight joints than to run the risk of permanently leaky joints.

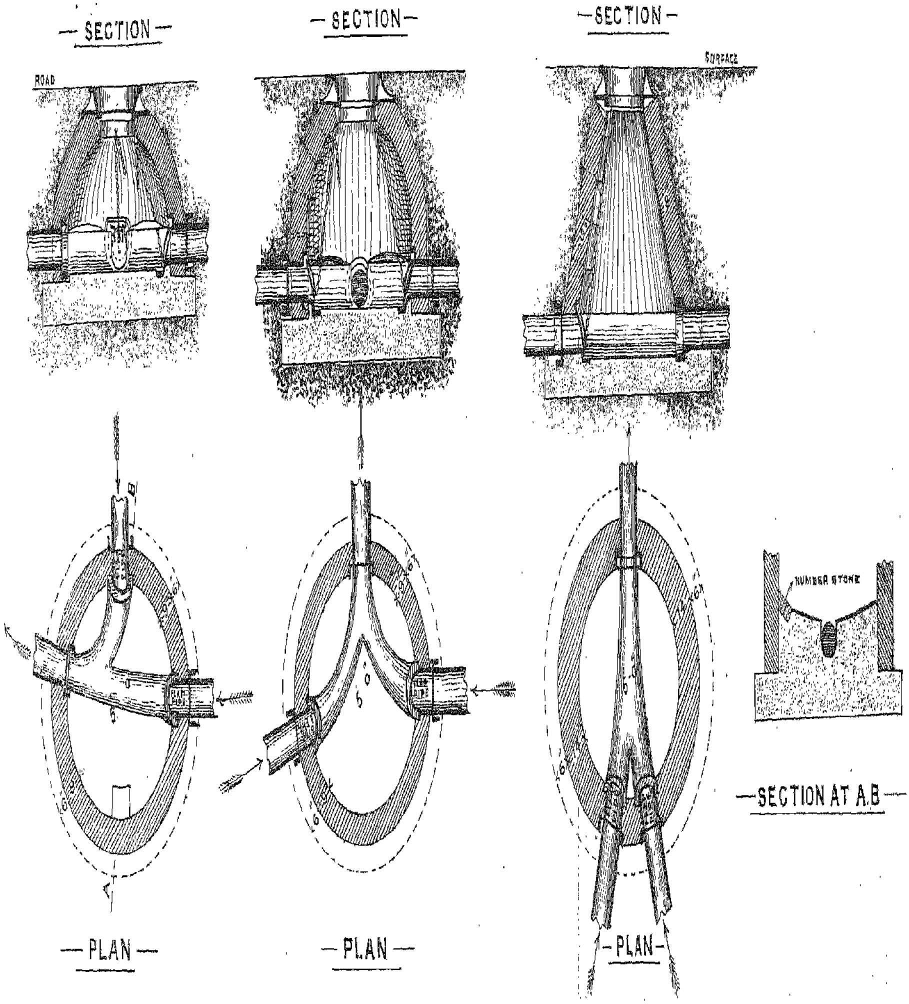
In Eastern countries, where the Banyan tree is much grown at the sides of roads and streets to give shade, much trouble is avoided by the use of patent jointed pipes, as the roots of the Banyan tree cannot be kept out of the pipes in their search for water even by cement joints. The mixture of tar and cement, which is sometimes used for jointing sewers in streets where Banyan trees flourish, has only been partially successful in Bombay. No Banyan root can find its way through a patent joint pipe, such as Hassall's or Sutton's.

It is difficult to say which of the patent joint pipes above described is the best. Those in which cement is used in combination with bituminous composition are superior to those used with bituminous composition only, and of all of them the Author favours the Hassall and the Sutton Patent Joints, and of these two joints the Sutton is the simpler of the two and more easily workable by pipe-layers in India.

Pipes should not be laid at too great a depth without a protection of concrete so as to resist the pressure of the covering material. A depth of 15 feet to 16 feet is recom-

DETAILS OF CIRCULAR MANHOLES ON PIPE SEWERS

SCALE 4 FEET TO 1 INCH



mended as the limit for 9-inch pipes and 12 feet for all larger sizes, and all pipes laid at these or greater depths should be laid on and covered with a layer of 6 inches of lime or cement concrete. Pipes, which are laid at a shallow depth, may also require a protection of concrete to prevent rupture by the weight of heavy traffic.

After all the joints have been carefully made and before the trench is filled in, what is known as the "disk test" and the "water test" should be applied to each length of pipes between manhole and manhole.

The former consists in passing a cylinder of wood, about half an inch less in diameter than the pipe, through the whole length of the sewer to ensure of its being clear of rubbish.

The latter test is made by closing the lower end of the pipe and filling it entirely with water, until a head of at least twelve inches is obtained in the upper manhole. If there is no fall in the level of the water after two hours, it may be taken that the joints have been well made and are water-tight and the particular length of pipes tested may be passed. This is an important test and should never be neglected, and should always be made whilst the pipes are still exposed.

Plate 7 gives the details of circular manholes on pipe sewers. They are constructed on lines of sewers for the purpose of inspection and cleansing. They should not be more than 200 feet apart, and the sewer should always be laid straight between manhole and manhole, so as to facilitate inspection and cleansing and to ensure there being no gaps or spaces in the joints of the pipes.

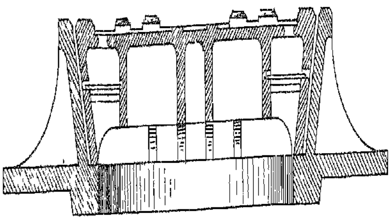
Manholes are usually constructed of brickwork set in cement and may be of any shape, though usually square

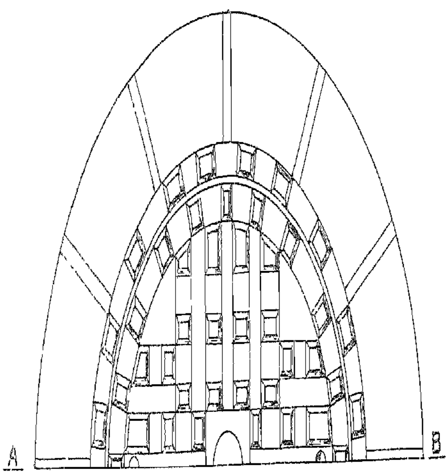
or circular. The thickness of the brickwork will vary, according to depth, from 18 inches to 9 inches. A manhole should usually be founded on a 12-inch layer of cement concrete. In the case of rock this may be reduced to 6 inches. The circular shape has found the most favour in Bombay, because on the removal of the cover the inspection of the whole of the floor can be at once made. Circular manholes will vary in their vertical section according to the depth and the kind of soil in which they are constructed, the dome-shaped section being recommended for depths up to 5 feet 6 inches, but for greater depths than the above the conical shape is always the best. The top and bottom of manholes are fixed in size for all depths. The sides of a conical shaped manhole at a depth less than 5 feet 6 inches would therefore so slope as to be dangerous to the structure and accordingly for manholes of less than that depth a dome shape is recommended.

It is desirable to render manholes both inside and outside with a half inch plastering of cement and sand in the proportion of one to one, so as to keep them absolutely water-tight. Step irons should be always fixed in the brickwork of manholes while being constructed, when the depth exceeds 4 feet. Each pipe entering or discharging into a manhole on a pipe sewer should be provided with a metal flap securely fixed to the pipe. The floor of the manhole should be made of cement concrete and half round channels formed in it, at the same gradient as the pipe and with vertical sides of the same height as the pipe, and finished off with a coat of cement well rendered. It is desirable in all manholes to place an indicator stone, with the number cut into it, near the top and under the cast iron frame. In a dome-shaped manhole it is not possible to

C.I. CIRCULAR FRAMES & COVERS FOR MANHOLES.

SECTION AT A.B.

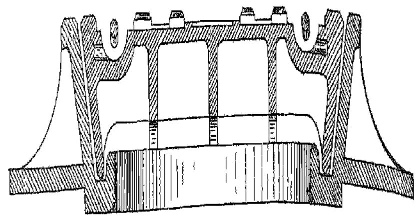


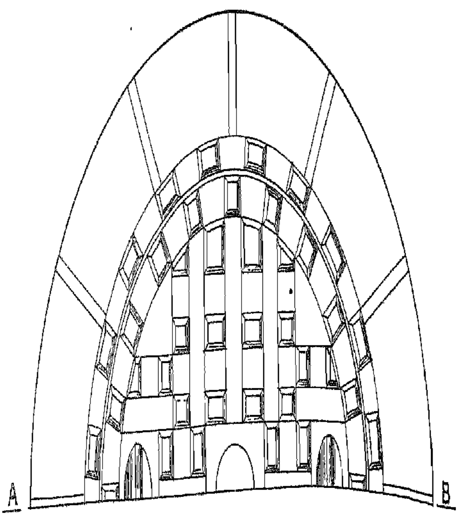


HALF PLAN

FIG 1

SECTION AT A.B.





HALF PLAN

FIG 2

place a stone under the frame so as to be seen and therefore it should be placed in the floor as shewn in Plate 7. Around the mouth of the manhole a fillet of cement and sand (1 to 1), should be placed for the reception of the cast iron frame, which should be so bedded on to the masonry of the manhole that the top may be slightly above the original surface of the road, this level being fixed so that no storm water may find its way into the manhole.

Plate 8 shews two patterns of manhole covers and frames in use in the Bombay sewerage works. Both are good types, but that shewn in Fig. 2 is the newer and probably the better. The weight of frame and cover should not be less than 6½ cwt. It will be noticed that the cover fits into a slot in the frame, which ordinarily is soon filled with sand from the road surface, and makes not only a water-tight but a fairly air-tight joint.

In cases where branch pipe sewers connect with man-

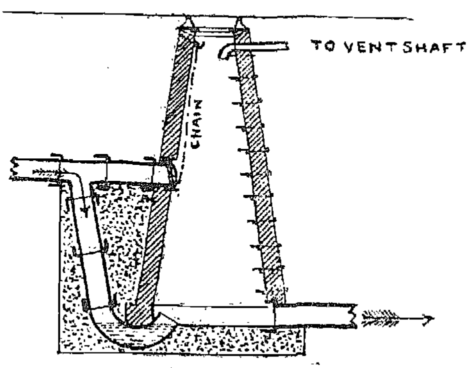


FIG. 21

holes on main pipe sewers at a higher level, a drop pipe should always be used as shewn in Fig. 21. As will be seen in the Figure, the branch pipe sewer is brought down at an angle and finished with a bend discharging into the

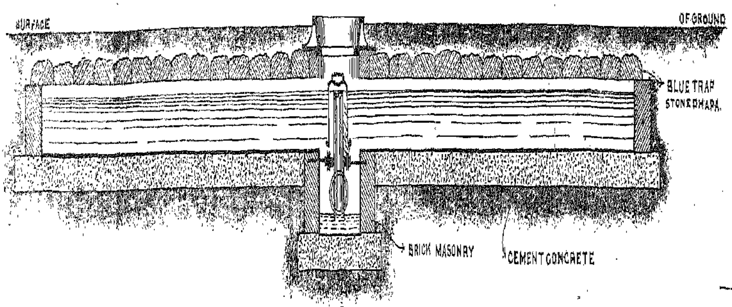
manhole at the main pipe sewer level, while an overflow and inspection eye is provided by continuing the pipe straight into the manhole and closing it with a metal flap valve. This arrangement avoids the splashing of the sewage in a manhole—a proceeding conducive to the generation of sewer gas.

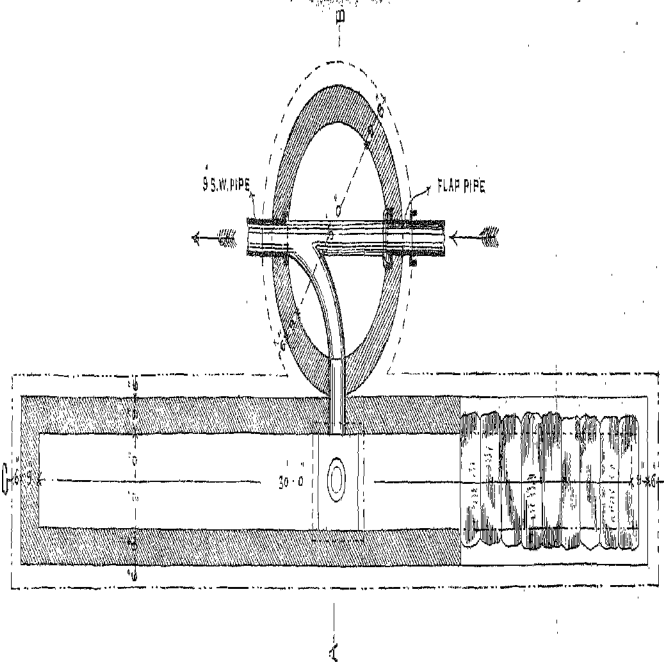
Flushing Tanks.—The provision of flushing tanks is very desirable in all sewerage schemes. The number and size of these tanks must depend to some extent on the gradients of pipe sewers and the class of sewage, but in general it is advisable to fix one at the head of each section. Plate 9 shews the type of flushing tank commonly in use in the Bombay sewerage system. The tank is constructed of brick-work in cement or hydraulic mortar and rendered with a half inch coating of cement and sand (1 to 1), and covered with stone slabs 6 inches in thickness, and having the man-hole frame and cover of the type before described fixed over the siphon. They are usually constructed to contain from 100 to 600 gallons according to the length and diameter of the sewer they flush. The flushing siphon is fixed in a chamber in the centre of the tank, the floor sloping both ways towards it. The lower end of the siphon dips into the water in the chamber and forms a trap. The water rises on the inside of the tank until it reaches the lip or adjutage and dropping over expels a quantity of air and this continues until a partial vacuum is formed and siphonic action is set up, and the whole of the contents of the flushing tank are discharged. Each tank is fitted with a tell-tale, connect-ed to a float, which registers each flush. The water-supply pipe should be provided with a reverse ball valve.

The connection between a flushing tank and a manhole should be constructed in the manner shown in Plate 12. A

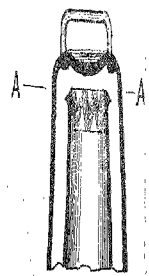
DETAILS OF FLUSHING TANK
WITH AUTOMATIC ANNULAR SYPHON
SCALE 4 FEET TO 1 INCH.

SECTION ON LINE C.D

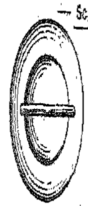




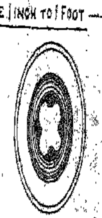
PLAN



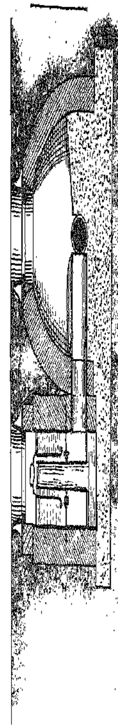
SCALE 1 INCH TO 1 FOOT



TOP PLAN



PLAN AT A.A.

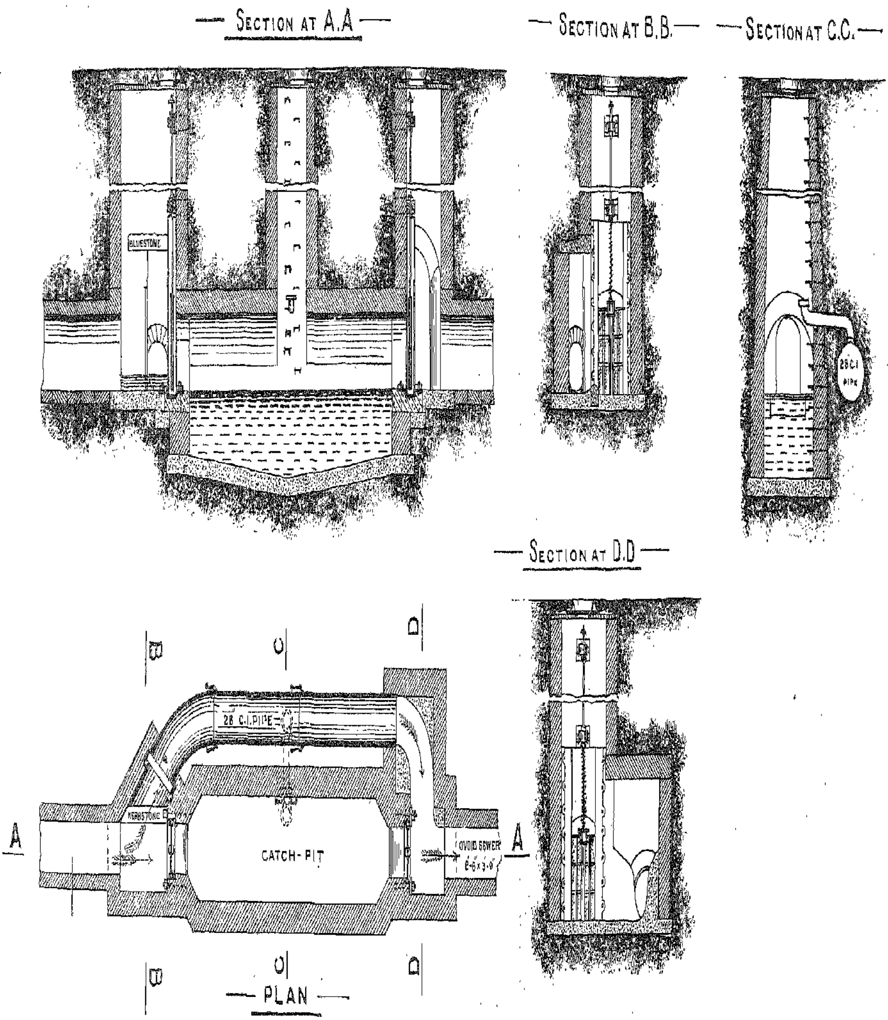


SECTION ON LINE A.B.

PLATE 10

CATCH-PIT ON OVOID SEWER (2-6 x 3-9)

SCALE 8 FEET TO AN INCH



6-inch cast-iron discharge pipe from the flushing tank is built into the wall of the manhole and carried down by means of a bend so as to terminate 2 inches below the top of the channel of the manhole. This bend is fixed to the wall by means of a wrought-iron strap, the details of which are given in the Plate. The floor of the manhole is inverted so as to carry the whole flush directly towards the outlet sewer.

Catchpits.—These have been found necessary in the Bombay sewerage system both for ovoid and pipe sewers and are recommended for general use in India. The principal reason for their adoption is on account of the large amount of mineral matter, in the shape of sand, ashes, and road detritus, which, as before stated, finds its way into the sewers through the branch drains from every point. The catchpits as constructed in Bombay are shewn in Plates 10 and 11. They have successfully stood the test of time, and year by year their number is being increased as the sewerage system is extended. In the districts sewered on the Shone system of drainage they are not required, because there it has been possible to adopt steeper gradients and thus to decrease the possibility of the deposit of solid matter. The construction of catchpits on ovoid sewers should be wholly in cement brickwork or masonry. They should be fitted at both ends with penstocks, as shown in Plate 10, and should slope towards the centre so as to facilitate cleansing. Each catchpit must be constructed with a cast iron by-pass, which is put into use only during the time of the cleaning of the main chamber. With catchpits on pipe sewers (Plate 11) the by-pass is done away with by having two chambers, both of which are ordinarily brought into use, except when the catchpit is being cleaned. Instead of a penstock these catchpits are fitted with sluice valves,

their size being governed by the size of the respective pipe sewer. Care should be taken in cleaning out these catchpits, for, when the silt is disturbed, they are apt to dangerously fill up with gas. There is no question as to the utility of these catchpits, at any rate in Bombay, as both small and large regularly fill with silt and require to be cleaned out at least once a month, and any scheme for the disposal of sewage with similar characteristics to that of Bombay would not be complete without such catchpits.

Flushing Doors.—Flushing doors, similar to tidal flaps as described in the catalogues of various manufacturers, are an undoubted aid to flushing large sewers, as by these means a great quantity of pure water, which would otherwise be necessary, is dispensed with. Broadly speaking, a flushing door is a hinged iron flap placed in a manhole on the inlet side of the sewer. This can be securely closed, when required, so as to head up the sewage on the upper length of the sewer to any required extent. On opening the door, which should be done as rapidly as possible, the whole of the pent up sewage rushes forward at a greatly increased velocity to that which would be obtained in the ordinary way, scouring before it solids and other matter which would otherwise tend to form a deposit on the invert of the sewer.

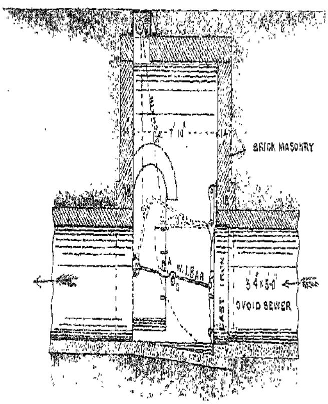
Large flushing doors, such as are used on the main ovoid sewers in Bombay, are provided with a hinged strut to keep them securely in their place when closed, and to this strut is attached a chain, which is used to lift the door to a horizontal position at the requisite moment.

A reference to Plate 13 will shew the door in its lowest position, and the hinged strut preventing it from opening. To release the door a chain is provided which is fixed to

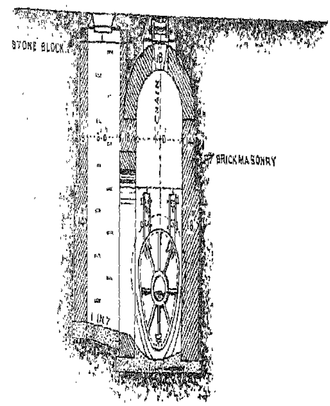
—Tidal Flap on an Ovoid Sewer 3'-4"×5'-0"— Plate No 13

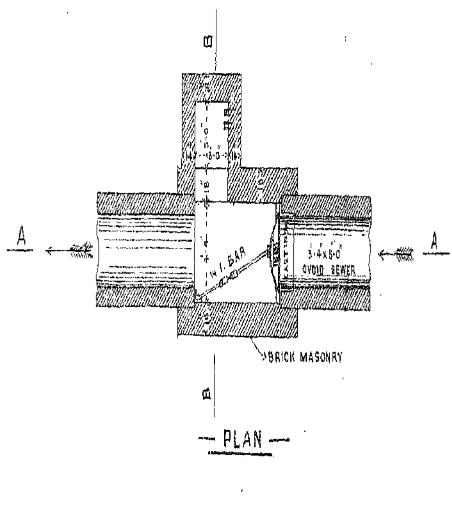
—Scale 8 feet to an inch—

—Section at A. A.—



—Section at B B—





—Plan—

the ring A on the strut. In the larger sized doors this is connected in a small chamber immediately below road level to a winding apparatus or to the lifting gear, as it is found impracticable to lift these doors by a direct pull. The joint B, on the strut being lifted, takes the position shewn by the dotted lines, and easily drops back into its proper place on the chain being released. These flushing doors have been found most useful in Bombay, where the accumulation of silt in the sewers is considerable. The following observations shew the result of one average flush :—

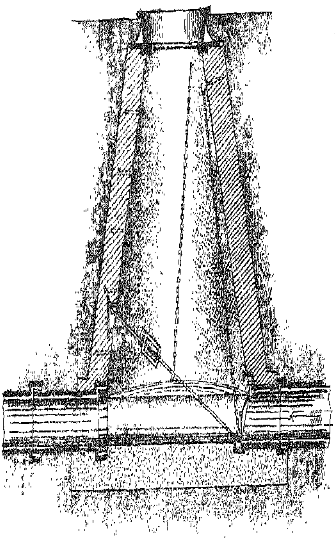
Size of Sewer 2'-6"×3'-9"	Depth of Silt before Flushing.	Depth of Silt after Flushing.	Difference in depth of Silt.	
			Increase.	Decrease.
	Ft. In.	Ft. In.	In.	In.
Manhole 5	1—11	1— 8½	......	2½
Manhole 4	2— 0	2— 2	2	......
Manhole 3	1— 9	1— 9	......	......
Manhole 2	1— 9	1— 7	......	2
Manhole 1	2— 0	1— 7½	......	4½
Flushing Door.				
Manhole 1	2— 2½	1—10	......	4½
Manhole 2	1—10	1— 9	......	1
Manhole 3	1— 9	1—10½	1½	......
Manhole 4	1— 4	1— 6	2	......
Manhole 5	1— 7	1—11	4	......

From these observations it will be seen that above the flushing door 2½ inches of silt have been moved forward

from No. 5 to No. 4 manhole, all manholes being 200 feet apart. In manhole No. 3 there is no difference after the flushing. In manholes 2 and 1, 2 inches and 4½ inches respectively have been moved forward. Below the flushing door manholes 1 and 2 shew a decrease of 4½ inches and 1 inch of silt, while 3, 4, and 5 shew an increase of 1½, 2, and 4 inches. These results are satisfactory for one flush and particularly when the distance between the manholes and the area of the sewer is considered. By continuing the flushes great good can be done in the way of cleansing the sewer. A somewhat similar method of flushing can also be used for pipe sewers, but the valve, which is preferably of a disk type, is in this case placed on the outlet from the manhole and an overflow from the manhole about 3 feet above the invert is usually provided, discharging into the outlet sewer. The object of this overflow is to guard against the risk of the door being closed and accidentally forgotten and the sewage in consequence forcing its way out of the lowest manhole cover. These small valves are inexpensive and undoubtedly useful, and might advantageously be placed a short distance from the head of branch sewers, simply leaving a sufficient length of sewer between the valve and the head manhole in which to store up enough sewage to create a satisfactory flush. In good gradients these valves should be built into the manholes at intervals of 1,000 feet, but if the gradient is flat then they should be placed at intervals of 500 feet.

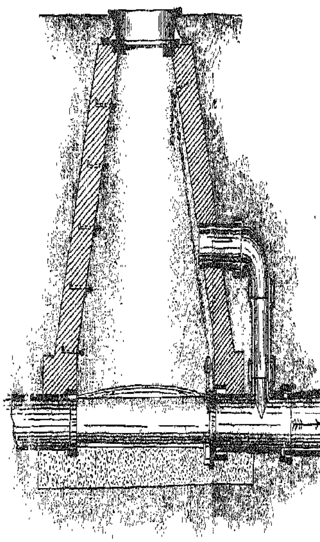
It must be borne in mind, when considering the adoption of appliances of this kind, that an efficient and separate permanent staff is necessary to work them.

FLAP-VALVES & DISC-VALVES ON PIPE SEWERS



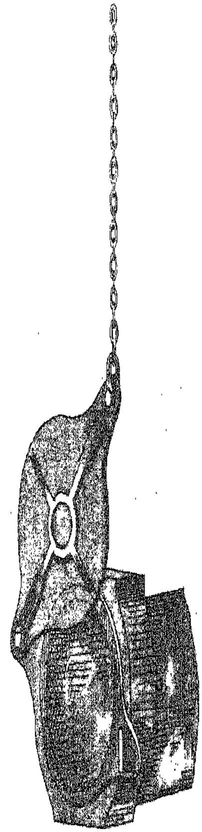
FLAP-VALVE

FIG. 1.



DISC-VALVE

FIG. 2.



SCALE 3 FEET TO AN INCH

Recently Messrs. Mather and Platt have introduced a flushing disc which effects the holding up and discharging of sewage automatically, and it is likely that this valve may render it possible to avoid the necessity of a permanent staff.

As an alternative to the disk valve, the flap valve shewn in Fig. 1 on Plate 14 is often used. It is fixed on the inlet sewer of a manhole and provided with a chain for opening and a strut for keeping the surfaces water-tight when closed. The flap is made of metal hung on hinges set with lead or cement in a stoneware block which is built into the brickwork of the manhole. A ring should be provided on the chain to fasten on to a hook just below the manhole cover, so that the flap can be kept wide open when not in use.

Ventilation.—One of the most important questions with sewerage schemes and one that has exercised the minds of Sanitary Engineers for many years, is the efficient ventilation of sewers. It is not alone sufficient to merely ventilate a sewer and keep it reasonably free of poisonous gases, but it is imperative that the ventilation should be so carried out as to cause neither nuisance nor injury to the public, and it is only by great care and judgment that these can be avoided.

Sewer gas has been described in Moore's Sanitary Engineering as a "Fœtid Organic Vapour," and this is a very apt description of it. Chemical analysis of the air in sewers shews it to generally consist of marsh gas (CH_4), Carbon dioxide (CO_2), Ammonia (NH_3), Nitrogen (N), and greater or less quantities of Sulphuretted Hydrogen (H_2S) according to temperature, and Carburetted Hydrogen (C_2H_4).

Carbon Dioxide, or choke damp as it is also called, is the result of decomposition and when inhaled in any

quantity causes instantaneous prostration, often followed by death.

The presence of Nitrogen in sewers is due to the denitrifying of the organic matter in the sewage, which is the first stage of the bacterial work. Carburetted Hydrogen in sewers is often due to the leakage of gas pipes, but more often in this country to the decomposition of vegetable matter. It has a faint smell something like burnt hay. In the Bombay sewers a large quantity of this gas accumulates. It is very explosive when mixed with atmospheric air and for this reason no naked lights should ever be used in sewers until after they have been fully tested as hereinafter described.

Marsh gas, which is analogous to Carburetted Hydrogen, is the result of decomposition of vegetable matter and burns easily with a blue flame when ignited.

Sulphuretted Hydrogen, a gas nearly always present in sewers, is also a product of putrefaction. It has a very offensive smell and is heavier than atmospheric air. It is the most poisonous of all gases and has been responsible for numerous deaths of workmen in sewers from time to time. It mixes freely with fresh air and becomes then comparatively harmless.

The ammonia present in sewer air is the result of bacterial action.

The mean temperature of the sewage in Bombay is about 76·5° while the mean temperature of the air as registered at the Meteorological Observatory, Colaba, on the average of the observations of 56 years is 79·60°. It is obvious that at a temperature of 76·5° in the sewers, putrefaction and therefore the discharge of foul gases from the sewers will be great, and the fact that the temperature

of the air is greater than that of the sewers is not in favour of successful ventilation.

Fresh sewage, however offensive it may be, is virtually harmless, but in its transit through sewers it becomes progressively noxious and dangerous.

Barometric changes effect the amount of foul air present in sewers. The lowering of the barometric pressure leads to the escape of gases in the sewage and favours decomposition and putrefaction, while an increase of barometric pressure enables the sewer air to carry a larger amount of vapour, and, therefore, for the sewage to retain a larger amount of these gases which are due to decomposition.

Increase of temperature of the liquid tends to expand the air held in the sewage, and consequently a quantity of the offensive gases is driven off under some pressure.

Temperature and barometric pressure are, therefore, very potent agents in connection with ventilation.

Steam, hot water, waste chemical products are all active agents in setting up decomposition in sewers and thereby freeing gas; soda water manufacturers are especially culprits in this way, and the discharge into a sewer of waste water from a soda water manufactory highly charged with carbonic acid gas has in Bombay prevented any access to the sewer in the immediate neighbourhood for days together.

Experiments made by the late Mr. Santo Crimp tend to shew that the direction and force of wind is a great factor in ventilation, and that Engineer has stated that ordinary ventilating shafts often act as inlets or outlets according to the condition of wind for the time being.

That sewer gas has the power of predisposing the human body to disease is, no doubt, true, though there is no

direct evidence to show that it is the immediate cause of zymotic disease, but it is quite conceivable that it is an indirect one. On the other hand, it is a curious fact that the health of employés at Sewage Pumping Stations compares very favourably with that of people living elsewhere, and this is borne out in Bombay. New-comers, however, often suffer and in divers ways, which would suggest that the poisons, if poisons they be, which surround such stations are such as people can soon become immune to.

The term "ventilation" is usually used to mean both the venting and the ventilating of sewers, *i.e.*, the letting *out and the letting in of air into sewers, but the two terms* should be kept quite apart as they mean distinctly different operations. Sewers should be vented and house drains ventilated.

For this reason all manholes on sewers should be made air-tight and the vent shafts, as they naturally do, may be allowed to act as inlets and outlets alternately in accordance with the Meteorological conditions prevailing at the time, and as the depth of liquid in the sewer for the time being falls and rises.

Sewers laid at sharp gradients require more care in venting than those on flat gradients, because the gas naturally finds its way to the highest point of the sewerage system, sewer gas being generally lighter than atmospheric air, but this may not be always so as with quick velocities the gas is sometimes carried along with the sewage.

Vent shafts should be as few as possible consistent with safety; the number being governed by the varying flow of sewage and the size of the sewers, care being taken *to provide sufficient to prevent the pressure of the gas* forcing the traps on the house connections, and they

should not be less than 6 inches in diameter. The distance between vent shaft and vent shaft should, as a general rule, not exceed 400 feet. This distance has been found in Bombay to be satisfactory, provided that all house connections are properly protected by an intercepting sewer trap and its accompanying vent pipe, and no special conditions prevail, such as the discharge of hot water or chemicals into the sewer. Under the latter conditions the shafts should be as close together as 200 feet.

The selection of the positions for vent shafts require careful consideration, and no hard-and-fast rule can be laid down in regard to them. They should, however, in all cases be as far removed from dwellings as possible, but, if the local circumstances oblige their erection near dwellings, they should be carried up well above the roof of the highest house within a radius of 200 feet. Sewer gas will travel long distances in the direction of the prevailing wind, and in a City like Bombay, where houses are, for the most part, open night and day, this requires that the greatest care should be exercised in fixing vent shafts. These shafts, when fixed against houses, are for the most part made of iron, which being a good conductor of heat has the effect of creating a draught from the sewer. Therefore, if possible, a vent shaft should be fixed where the sun can shine on it for as many hours as possible.

The greatest care should be taken to see that all the joints of a vent-shaft are most carefully made, as this is most important.

The usefulness of vent-shafts depends on the difference of the pressures of air at the outlet and the inlet of the shaft, less the loss caused by frictional resistance.

In designing a vent shaft, it should always be remembered that the frictional resistance of the shaft modifies the current, the amount being in direct proportion to the length and inversely as the diameter or area of the shaft. Vent shafts should, therefore, err on the side of being too large rather than too small, and should be of the same size from top to bottom. The nearer the sectional area of the vent-shaft is to that of the average air space of the sewer it vents, the more efficient will it be.

In any system of sewer ventilation, simplicity and independence of mechanical aid is desirable. Natural ventilation should be made use of as far as possible and gases on leaving the outlet of a vent shaft should be exposed to as much dilution with fresh air as possible.

It must always be kept in view that just as much fresh air, as is admitted into the sewers, must leave those sewers again as foul air.

The question of sewer ventilation is a very difficult one, and the last word has not been spoken in regard to it.

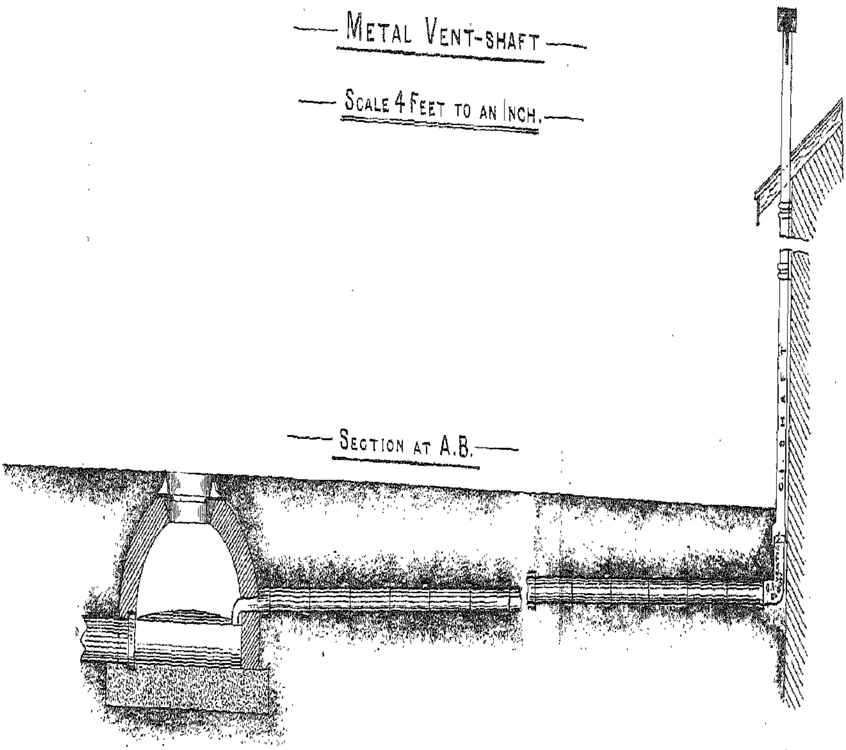
Some authorities now hold that sewer air has a greater density than atmospheric air and does not rise as is generally believed, but is forced out of the sewers by the rise of the sewage or by the formation and pressure of the putrefactive gases in the sewer.

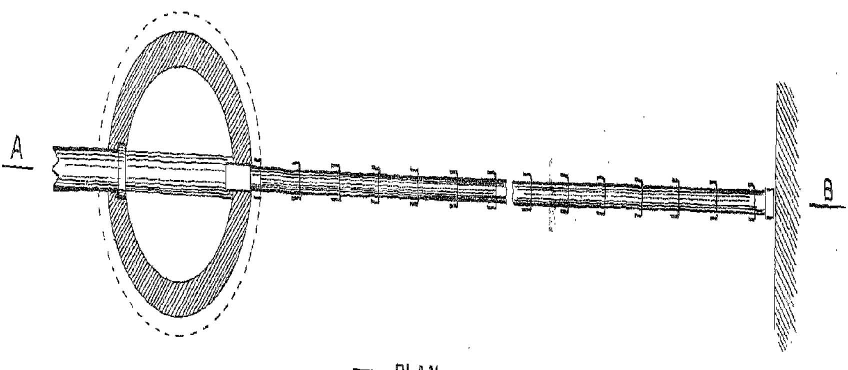
Some years ago in a section of the Bombay Sewerage System it was decided to try surface manhole ventilators fitted with charcoal trays, a system which has been much used in England. Charcoal, to be at all effective as a disinfectant or a deodorant, must remain in a dry state, and it is manifest, therefore, that in Bombay with its humid atmosphere, it would not be successful. As a matter of fact, the manhole perforated covers in the dry weather

METAL VENT-SHAFT

SCALE 4 FEET TO AN INCH.

SECTION AT A.B.





PLAN

allowed a quantity of sand and rubbish to enter and mix with the charcoal, completely filling the interstices and rendering it useless, and in the monsoon they admitted a quantity of rain water into the sewers with washings from the streets.

Plate 15 gives a drawing of an ordinary metal vent shaft as used in Bombay. It is rectangular in section and is 7½ inches by 4 inches. A masonry shaft or sometimes an iron column is used in places, where there is no building to which a metal shaft can be fixed.

When Shone's Hydro-Pneumatic System is used, the ventilation of the sewers in each sub-district is carried out by a number of inlet shafts, and by one outlet shaft, the latter being used for the double purpose of disposing of the exhaust air after use in the ejector, and of ventilating the gravitating sewers. The process, which has been partly described in an earlier Chapter, *vide* Plate 4 and page 22, is that the air, which enters the ejector at a pressure higher than that of the atmosphere, and leaves it after ejecting the sewage at about the same pressure, is made use of to create a draught in the outlet shafts. These, being connected with the pipe sewers, draw the foul air from them, its place being supplied by fresh air entering the sewers through the small inlet shafts erected at the head of each gravitating sewer. The experience gained in Bombay shews this system to be very successful, but the drawback is, and it is a serious one, that the sewer air is discharged into the atmosphere in large puffs; and often, before it can be sufficiently diluted with fresh air and rendered harmless, it is borne by the prevailing wind into houses within 200 feet in the direction of the wind. It is, of course, impossible in a City, where huge buildings of five, six, and seven stories exist, to construct iron

columns of such a height as to be out of all danger, and therefore some means of destroying the gas, before it leaves the shaft, are a great desideratum. This can be done in both gravitation and sectional systems of sewerage by passing the gas over a lighted Bunsen or other suitable burner by which means the offensive and dangerous products of sewer gas are destroyed. There are several kinds of apparatus now in the market for dealing with the sewer air in this way, the combination of the street gas lamp and the vent shaft being a favourite and successful method but, as very few Indian towns are lighted by gas, this would have to give way to some adaptation of the more usual kerosine lamps.

Recently Mr. Shone has patented another system of ventilation, which he calls the "20th Century System of Ventilation," and it will not be out of place here to give a brief description of it. The general principle, on which the system is based, is the creation of a partial vacuum in sewers, and admission of controlled volumes of atmospheric air through patent valves on the house connections, all other inlets to the sewers being either stopped or trapped. The partial vacuum, which is equal to about half an inch of water, is produced by means of an exhaustor fan driven by some motive power such as steam, electricity or compressed air. The air, removed from the sections of sewers thus dealt with, is discharged through one vent shaft fixed in connection with the fan.

It is evident that if the proportion of the atmospheric air is very large as compared to sewer gas, the resultant mixture can be safely discharged into the atmosphere without causing any nuisance. For this scheme to be successful, it must have the sewers or the system of

sewers absolutely air-tight, and any leaky joint or manhole cover would militate against the successful working of the whole system. There is no experience yet of the working of this system on a large scale, so far as the Author is aware.

There is another system which has been adopted on certain drainage schemes in England, and which aims at deodorising and rendering harmless gases issuing from either manholes or vent-shafts.

This system is known as the Reeve's System, and a brief description may be of use. Two porcelain receivers are fixed in a manhole and connected with the water-supply of the town. The lower receiver is filled with a proprietary material, chiefly consisting of Manganate of Soda. The upper receiver is charged with crude Sulphuric Acid. This Acid is allowed to drip slowly on to the Manganate of Soda, causing the Manganate to be converted into Permanganate which is a powerful oxidiser and deodorant. The Permanganate is then passed over a sprayer worked by the water-supply and the whole liquid thrown into fine vapour which disinfects and deodorises any foul gases. The apparatus costs about Rs. 180, and consumes about 300 to 400 gallons of water per day, and the chemicals cost about Rs. 60 per annum.

Removal of Obstructions in Sewers.—In India sewers and pipe sewers are very liable to obstruction and chokage. The universal habit of cleansing cooking utensils with sand, and the frequent use of broken tiles and road metal in latrines already referred to, are the principal causes. In Bombay the usual method of keeping the ovoid sewer clear of deposit or silt is to draw a shield or scraper through the sewer by means of a winch and a chain. This

shield or scraper is made of wood and in two patterns, one with the bottom part cut off, and the other with the top cut away about a third of the distance down. Both are constructed of the same shape as the sewer, and with wheels both at the bottom and the sides, and are of a size to leave about 1½ inch play on each side, to give greater facility in moving. The shield or scraper is dragged through the sewer from manhole to manhole, the sewage finding its way with increased velocity, either over or under the scraper, and thus softening the silt in front. The silt is pushed forward before the moving scraper into the nearest catchpit or goes on to the pumping station, where it is lifted with the sewage by the pumps. The scrapers are so constructed as to take to pieces; every part being bolted together when required for use. This is necessary, as the scrapers have to be put together in the sewers, and even then a specially large manhole is sometimes necessary to allow the larger part of the scraper being introduced into the sewer. The above method has been found to be the only means of moving the heavier particles of silt in the sewers. It has the disadvantage, however, of being destructive to the cement plastering of the sewer.

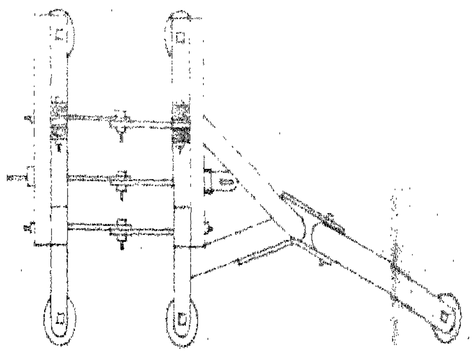
Where the silt is very hard, the scraper mounts on to the top of it, instead of moving it forward, and this frequently happens where it is practically impossible to do any repairs.

Plate 16 shews the apparatus in detail.

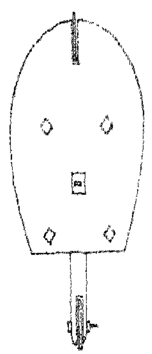
For pipe sewers usually a double disk as shewn in Fig. 22 is used and dragged through them, the silt being removed by hand at the nearest manhole. This arrangement is probably as satisfactory a way of cleaning

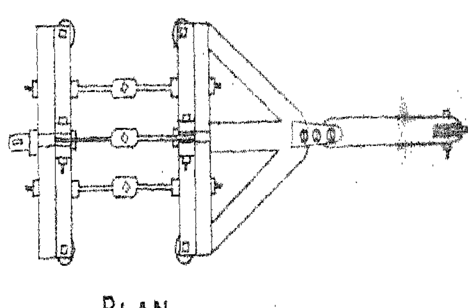
Scraper for Ovoid-Sewer

Side Elevation



Elevation





Plan

pipe sewers by hand as can be arranged, and has been in use in Bombay for some years. At one time an attempt was made to clean pipe sewers by placing a round metal and hollow ball in the sewer nearly the same size as the sewer and allowing the sewage to force the ball forward, but the attempt was not satisfactory, as the ball stuck hopelessly in the silt in the sewer and had to be dug out.

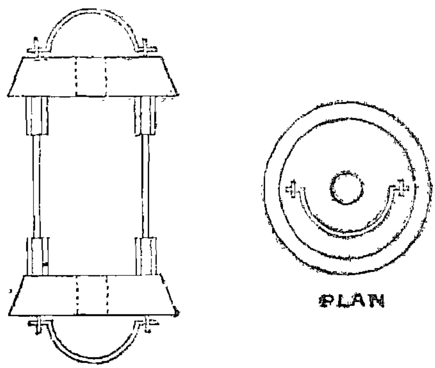


FIG 22

Rules to be observed in cleaning Sewers.—The following precautions should be taken, when men are required to enter and work in sewers or drains.

When only two men are engaged in opening a manhole, it must be securely fenced round before the cover is removed, and the fencing must not be removed until the cover has been replaced. This precaution must be very carefully observed in order to prevent accidents to traffic, the liability for which may be brought home to the body responsible and heavy damages claimed.

If there are more than two men engaged, the cover may be removed before the fence is erected, or the fence removed before the cover is replaced, provided that one man, not below the rank of a Foreman, shall be stationed at the open manhole and not leave it so long as it is open. An open manhole, whether fenced or unfenced, is never to be left

without some one on guard to prevent accidents, and he must not leave the manhole so long as it remains open.

Workmen are on no account to enter a manhole except under the immediate orders and in the presence of the Chief Inspector or of an Inspector, Sub-Inspector or a muccadum, who has satisfied the Chief Inspector that he understands, and is competent and may be trusted to apply the tests, prescribed in these rules, for determining the quality of air in a sewer.

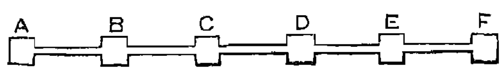
Workmen are on no account to go up a sewer beyond the manhole except under the orders and in the presence of the Chief Inspector, Inspector, or Sub-Inspector.

The first duty of the person in charge of men entering the sewer, drain, or manhole is to see that he has supplied himself with the following appliances :—

(*a*) chemical test papers ; (*b*) lights ; (*c*) bamboos ; (*d*) windsails ; (*e*) strong ropes and cords ; (*f*) driver's air pump (or blast fan) ; (*g*) air tubing ; and (*h*) picks, phaoras (native shovels), pails, gamels and whatever implements may be required for the actual work.

Not less than six manholes, at least two in each direction above and below, should be open when it is intended to enter either a sewer or a manhole.

The following sketch of a sewer with a series of six manholes in succession (A, B, C, D, E, & F) will illustrate the system to be adopted :—



All the six manholes must be open for free ventilation for an hour or more before a man enters a sewer or a manhole.

At B and also at E a windsail must be erected with the flaps kept extended towards the direction from which the wind blows.

The work will commence either at C and proceed towards D or at D and proceed towards C.

Assuming that the work begins at C, then a diver's air pump or blast fan with a flexible air tube must be set up at C, and kept constantly at work. Before a man enters a manhole, the air pump or fan must be worked for five minutes; and before going into a sewer beyond the manhole for ten minutes.

A competent man, according to the instructions contained in the above rules, must be placed in charge of the work, and he must satisfy himself by inspection at first and from time to time afterwards that the sewer is not dangerous to work in.

It must not be overlooked that, although near a manhole, the air may be pure, yet further within the sewer it may be fatal to life, and if a fatality should occur, it is as well to remember that a charge of culpable negligence may be brought, and very rightly, against an officer who orders a man to work in a sewer in which proper precautionary measures have not been taken.

Before the following tests are applied, the silt deposit at the bottom of the manhole must be first thoroughly stirred up with a rod or bamboo so as to agitate and dissipate the noxious gases which would otherwise be a serious source of danger when disturbed by the workmen's feet.

Chemical papers for testing the presence of Sulphuretted Hydrogen gas are always to be used.

If a paper, after five minutes' exposure in the sewer, turns a deep brown or black, the sewer is dangerous to

work in, and further ventilation must be allowed and the testing repeated before entrance is permitted.

If the paper test is satisfactory, a light may next be let down into the sewer by means of a cord running over the end of a staff. The light must be a naked light, that is to say, if placed inside a lantern, the door of the lantern must be open. This being a test not only for choke damp, but also for combustible gas or fire damp, no one must stand near to or over the manhole while the test is being applied. If the light burns unnaturally or goes out, the men are not to descend.

Even if the tests have been made and found satisfactory, no man is to go down with a naked light, but only with a Davey safety lamp, and one such lamp, if men are working in a covered part of the sewer, must always be kept 20 feet in advance of where the men are at work, and they must be cautioned to observe that it burns properly. If it does not do so or goes out, the men are all to return to the nearest manhole immediately and ascend to the surface.

No man shall, on any pretext, be in a manhole or sewer with a naked light, and on no occasion shall he smoke in the manhole or sewer or strike a match.

No man shall enter a manhole when the sewage is above the crown of the arch of the sewer or top of the pipe; but should it be absolutely necessary to do so, the greatest care shall be taken to watch the sewage, and in the event of its falling to within 2 inches above the crown of the arch or top of the pipe, the men are immediately to come up and not to re-enter the manhole until 15 minutes after the sewage has fallen below the crown, and fresh tests of the condition of the sewer have been applied.

Each man is to be fastened by a stout rope passing under his armpits and with a knot against his spine. The rope is to be kept from slipping down to the lower part of the body by means of short pieces of cord passing over the shoulders.

The foremost man must have the end of the tube, supplying fresh air from the fan always a little in advance of him, and he must carry it himself if possible; should the latter not be found practicable, another man must be employed to carry the air tube.

In any case one man must always be stationed at the bottom of the manhole to give an alarm and render assistance if required.

The men are to be cautioned that if they feel any difficulty of breathing (or feel unwell in any respect), they are not to remain in the sewer, but to come up immediately.

No man is to be allowed to remain in a sewer more than half an hour at a time.

At least three men must be stationed on the surface of the manhole, from which work is being carried on.

When the work has been completed from C to half the distance between C and D, the work will be begun from D and proceeded with towards C, similar arrangements and conditions being observed.

These instructions for executing the work between C and D will apply to carrying out the work between any other two manholes, the windsails, air pump, or fan and other appliances being moved as required.

Should an accident occur, every person in the sewer must be brought to the surface as rapidly as possible, and whilst they are being so brought out, crowding around the

manhole must be prevented, because a crowd would check the escape of foul air or the entrance of fresh air.

If any person brought out of the sewer is insensible and medical attendance cannot be immediately obtained, some of the following should be adopted :—

(*a*) Loosen all clothes about the body.

(*b*) Dash water on the face which should be turned towards the wind.

(*c*) Lay the man flat on his face with one of his arms under his forehead, and

(*d*) open his mouth, draw his tongue forward, and cleanse his mouth and nostrils with water, or

(*e*) turn him on one side while supporting his head, and turn him back again on his face.

(*f*) If breathing does not commence, turn him again gently on to one side and then on to his back.

(*g*) Raise his head and shoulders.

(*h*) Grasp both his arms just above his elbows and draw them gently but firmly upwards, and keep them in that position two seconds.

(*i*) Lower his arms and press them gently against his sides.

(*j*) Continue to raise and lower his arms as described until breathing is restored or until the man is placed in charge of a doctor.

(*k*) If breathing is restored before the doctor is obtained, rub the man dry and wrap him in warm dry clothes. Do everything possible to restore warmth and circulation.

(*l*) As soon as the man can swallow, give him warm water or any kind of diluted spirits to drink.

CHAPTER III.

Public Conveniences.—All Indian towns of any size should be supplied with public conveniences in the shape of latrines and urinals, as otherwise road-side drains or odd corners will be made use of, and these in a tropical climate soon become offensive.

Generally far too few conveniences are provided and that this is the case even in Bombay is evident from the use made of those that do exist, it being not uncommon to see persons awaiting their turn outside latrines and urinals. There is no doubt also that these conveniences serve the double purpose of preventing the committal of nuisances in the streets and of educating the lower classes to the necessity for sanitation and to the desirability of decency. It is almost incredible, but none the less true, that a large number of the poorer classes still require positive assistance in such an apparently obvious matter, as the correct direction to face when using privies. Two devices are commonly employed—a small looking glass fixed on the front wall of the latrine, about 3 feet from ground level, or the mark of an outspread hand painted in red by means of a stencil. The vanity inherent in the very humblest human beings makes certain that the glass will be faced with keen inquiry, while religion ensures, among Hindus at least, that no backs will be turned to the sign of the hand. The imprint of the open hand has long been regarded by both Hindoos and Mahomedans as a sign of plenty, and when placed on a wall of a building, it is intended to invoke a blessing not only on the building itself, but on the inhabitants thereof. In consequence many castes will not volun-

tarily turn their backs on the sign, which appears to offer bountiful charity and plenty.

The word "latrine" is used to describe a convenience either on the dry or the water-carriage system.

Dry Pattern Latrines.— Plate 2 gives a drawing of a range of dry pattern latrines much in use, either in connection with a cesspool or a sewerage system.

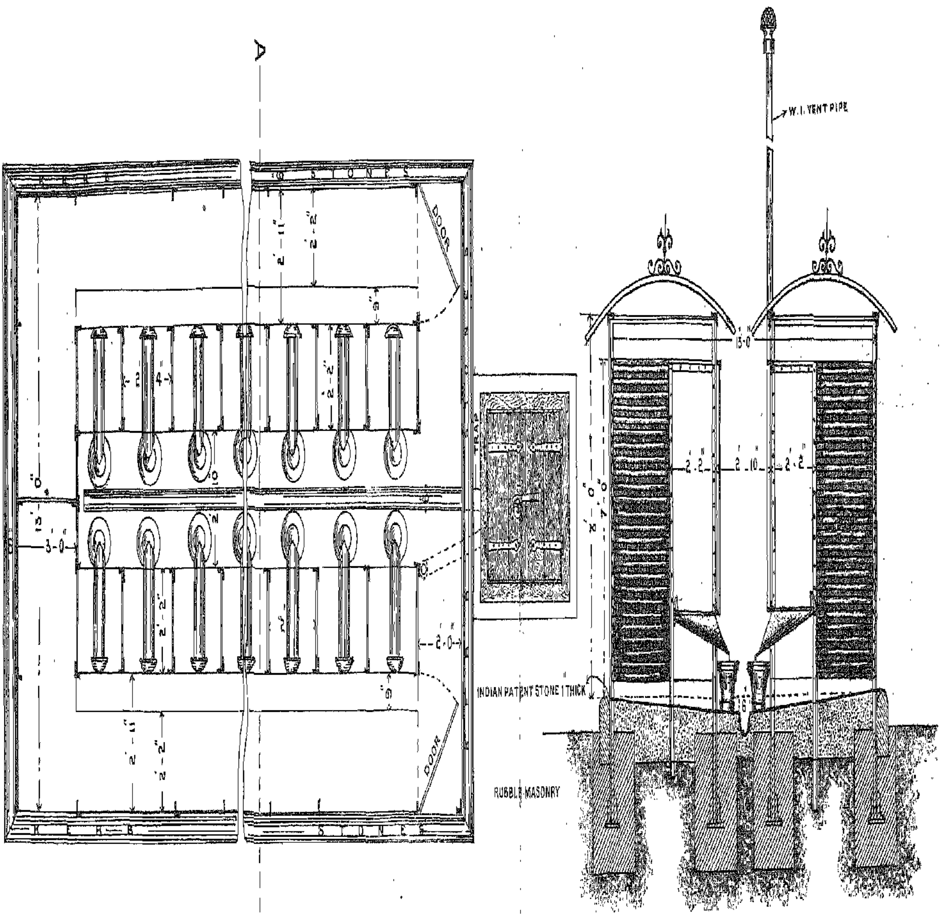
In these latrines the night-soil is deposited in a basket, which retains the solid matter and allows the fluid to pass through the interstices into a trap, connected to a pipe drain, and from thence to the cesspool or sewer according to circumstances.

A basket can hardly be called a satisfactory receptacle, as in no possible way can it be kept thoroughly sanitary. The division of the solid matter from the fluid in this way is most undesirable, because not only is the outside of the basket fouled, but also a large portion of the cemented space on which the basket is placed; and if this is not constantly flushed, it becomes a source of considerable nuisance; while flushing causes large quantities of water heavily charged with night-soil to pass into cesspools or drains not intended for such fluid. This is a frequent source of great nuisance.

Plate 17 gives a drawing of a range of the Crawford System Latrines, so called because they were introduced by the Municipality when Mr. Arthur Crawford was Municipal Commissioner. In this class of latrines the solid and the fluid matters are collected in one bucket, the contents of which are removed by hand daily, or more often if necessary. This is more sanitary than the basket system, and provided the buckets are regularly and fre-

PLAN SHOWING DETAILS OF
CRAWFORD SYSTEM LATRINES

SCALE 4 FEET TO 1 INCH

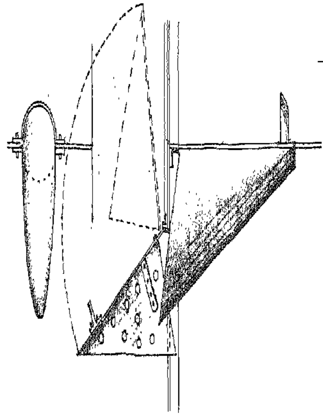


PLAN

SECTION ON LINE A.B.

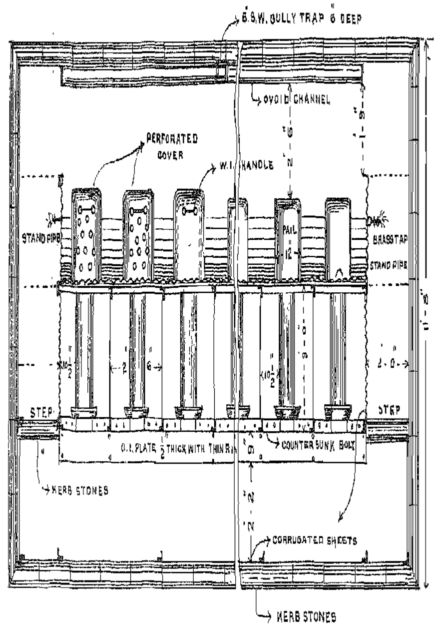
IMPROVED DRY SYSTEM LATRINES

SCALE 4 FEET TO 1 INCH



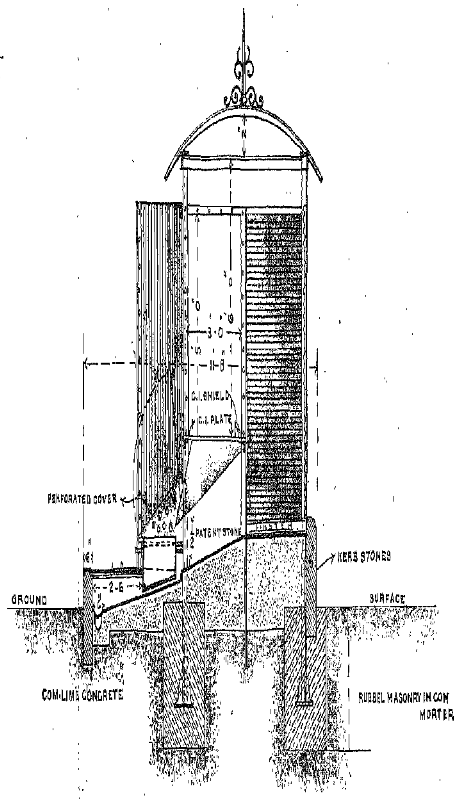
DETAILS OF C.I. PLATE, SHIELD, SHOOT & PERFORATED COVER

SCALE ½ INCH TO 1 FOOT



PLAN

CROSS SECTION



quently emptied there is little objection to this method. No connection from the latrine to a cesspool or sewer is required, the whole of the excreta both liquid and solid being removed by hand.

Plate 18 shews a range of Improved Dry System Latrines which are similar to the Crawford System, but differ in so far that the receptacles for the solid and fluid matter are covered with iron perforated covers.

In both the above latrines, the sloping shoot, which is usually constructed of wrought-iron, requires to be daily cleaned and brushed by the attendant in charge of the latrines. The shoots, as also the receptacles and their covers, should be well tarred or dammered from time to time. Tar is credited with considerable and lasting deodorising and antiseptic properties, and every application not only probably exerts these influences but covers up with an impervious skin any offensive matter that may have adhered to the shoots, etc. Although its use has been sometimes deprecated, there can be no doubt that for the special purposes for which it is recommended, it at present stands without a rival. Both latrines can be economically constructed on a masonry or concrete foundation with a cement flooring, the superstructure being of light angle iron standards with sides and roof of corrugated or sheet iron.

The size of a range of dry pattern latrines, *i.e.*, the number of seats it is to contain, is best arrived at by determining the population likely to use the latrines per day and allowing one seat for each 20 adults.

A convenient way of constructing a range of latrines is to place them back to back, those for males being on the one side and those for females on the other, with a 4-foot

paved gully between for the removal of the basket or buckets and for cleaning purposes.

Latrines on Water-Carriage System.—Wherever possible, latrines on the water-carriage system are to be preferred to those on the dry system. Many forms of this class of latrine have been tried in Bombay with varying success, and of late years very great improvements have been made. It is only recently that manufacturers have constructed a porcelain or glazed stoneware pan of a shape agreeable to the natives of India. Previous to that cast-iron was made use of, as shown in Plate 19, and sometimes stone or concrete. This cast-iron pan was never very successful, for it was difficult to keep it clean, and, as it could not possibly be made entirely smooth, it consequently soon became coated with fœcal matter. The cast-iron pan is now practically obsolete, the porcelain or stoneware pan being largely used in both public and private water-carriage latrines in Bombay.

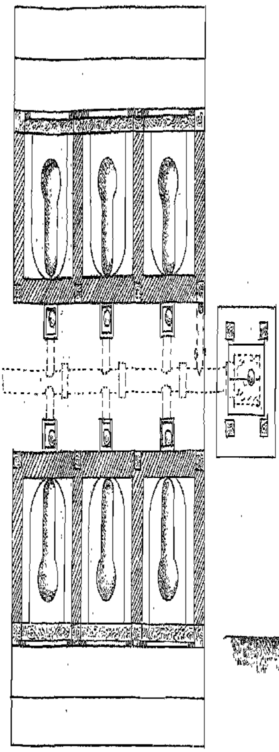
As shown in Plate 19 the latrines are placed back to back, the contents of the pans discharging through a 4-inch T discharge pipe into a gully trap connected with a pipe drain. At the higher end of this pipe drain there is usually fixed a flushing tank, fitted with an ordinary Field's automatic flushing siphon.

The compartments are usually built 2 feet 6 inches by 3 feet,—a size found to be sufficiently large. (In one town in India a latrine was built with much larger compartments and attained an altogether unexpected degree of popularity, it being used as residential quarters).

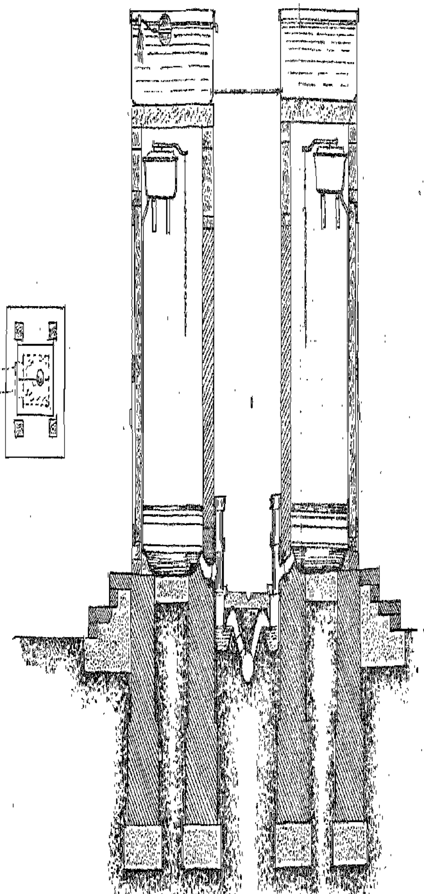
Each compartment was originally provided with a three-gallon flushing tank fitted with a pull-off chain and a ball-cock, but it was found that these chains were constantly

WATER CARRIAGE LATRINE WITH C.I. PAN

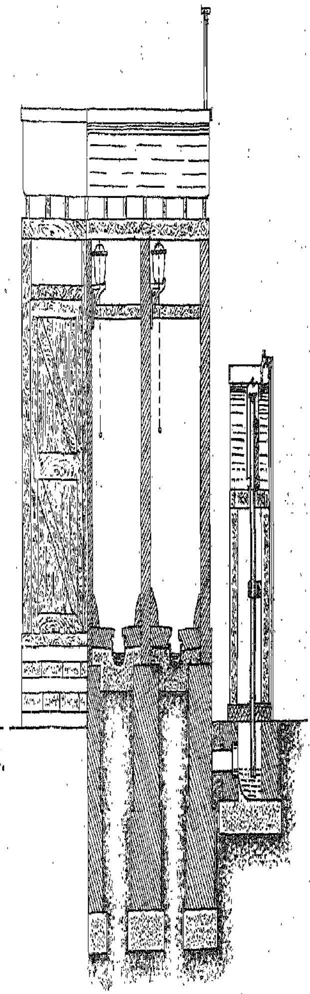
SCALE 4 FEET TO AN INCH



PLAN



CROSS SECTION



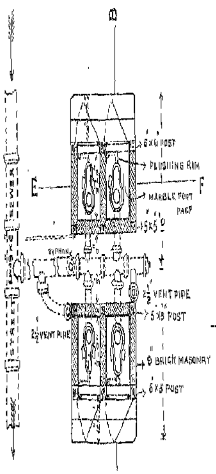
PART ELEVATION
& PART LONGITUDINAL SECTION

PLATE No 20

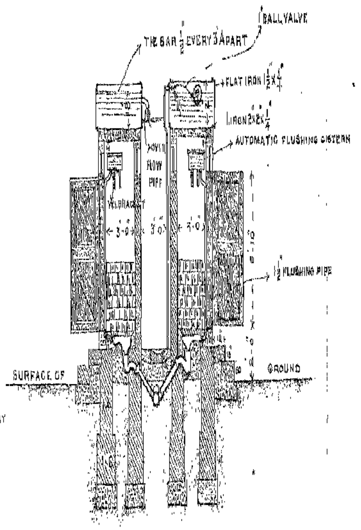
IMPROVED PATTERN OF LATRINES

FOR NATIVES

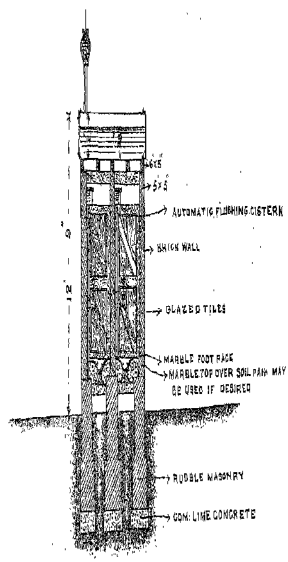
SCALE 8' FEET TO 1 INCH.



PLAN



SECTION ON LINE A.B.



SECTION ON LINE E.F.

being jerked off and stolen, and later a rod was substituted for the chain, but with no better success. Finally, automatic flush tanks were successfully substituted for these pull-off flushing tanks, but this class of flushing tank, unless carefully watched, is very wasteful as regards consumption of water. It should be carefully adjusted to discharge four times daily, or as many more times as circumstances may show to be necessary. On the top of each range of compartments is placed a water storage tank running the whole length of the latrine, fitted with a ball valve, and containing about 500 gallons so as to provide a storage of water for the latrines in case of an interrupted supply from the water main. This storage tank may not be necessary in all places or if a constant supply in the mains can be depended upon.

Plate 20 gives a drawing of the newest water-carriage system latrine now in use in Bombay. In this a porcelain pan is substituted for the antiquated cast-iron form, and the inside of each compartment is lined to a height of 3 feet with white glazed tiles. Each latrine is fitted with a 3-gallon automatic flushing tank, fixed on brackets at such a height as to be out of reach of interference. The soil pan is flushed from the front and also by means of a flushing rim, which surrounds the top of the pan. Foot rests are also provided in the proper positions for the users to squat on. The special trap used in the old pattern latrine is here done away with and the contents of the pan are discharged through an ordinary trap direct into the pipe drain.

Brass is especially esteemed by the natives of India, and it is not uncommon in these latrines to find brass handles and other fittings stolen. For that reason all

fittings should be preferably of iron and bolted to whatever they may be attached to.

In connection with an installation of latrines, it is desirable to provide a few small seats in the enclosed space for children. A properly paved and drained washing place is also necessary, the water supply pipe being fitted with an ordinary brass plug tap.

In public latrines on the above system, it is usual to fix the number of seats on the basis of one seat for each 50 adults, who are likely to use the latrines per day.

Trough Pattern Latrines.—In some places it will be found that trough pattern latrines have advantages over those on the water-carriage system. They are more suitable when required to accommodate large numbers of people, and for that reason are especially adapted for Mills and Factories.

There is practically no limit to the number of persons who may make use of a trough latrine daily and there are no fittings which can be in any way tampered with. The structure can be made of corrugated iron or some such cheap material or masonry, latrines built of the latter material being naturally more lasting.

Plate 21 gives a drawing of a trough pattern latrine, which has given general satisfaction. In this latrine a depth of 6 inches of water always remains in the trough, which is generally constructed of a half 6-inch or 9-inch stoneware pipe according to the number of seats. The trough is, automatically or at will, flushed from a 50-gallon flushing tank placed at its higher end. The form of the pan at its top is similar to that of the water-carriage latrine last described, with the lower half cut away and

TROUGH PATTERN LATRINES

SCALE 8 FEET TO 1 INCH

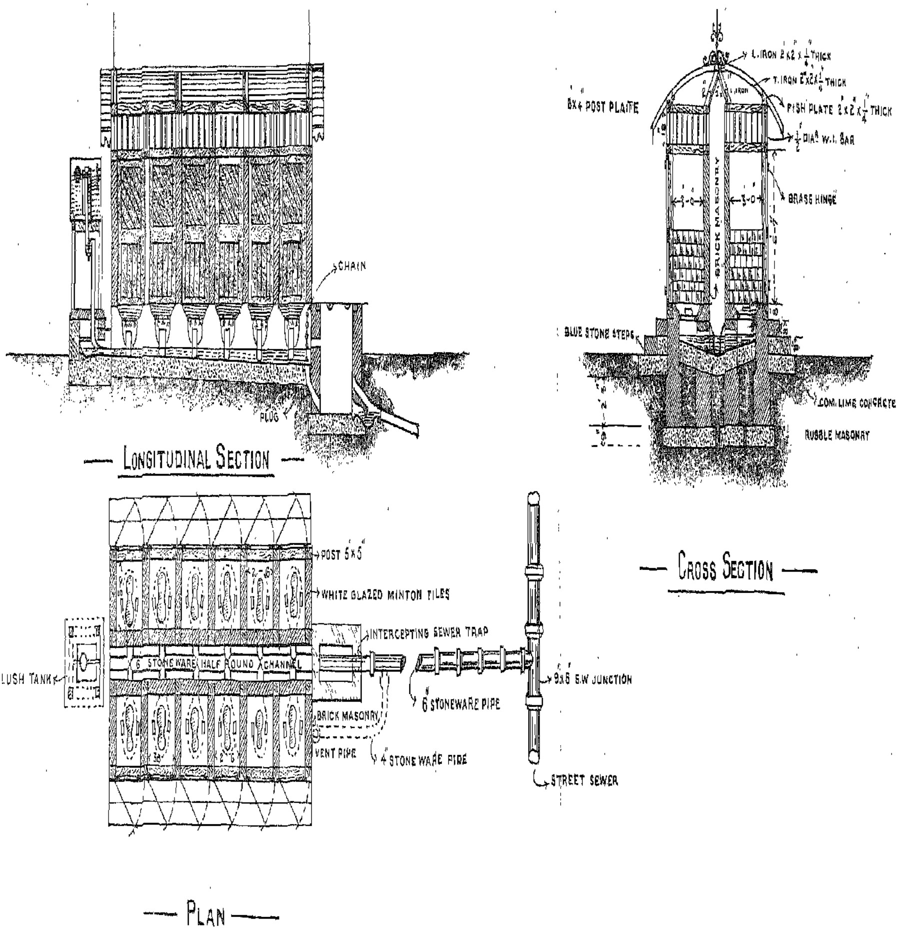
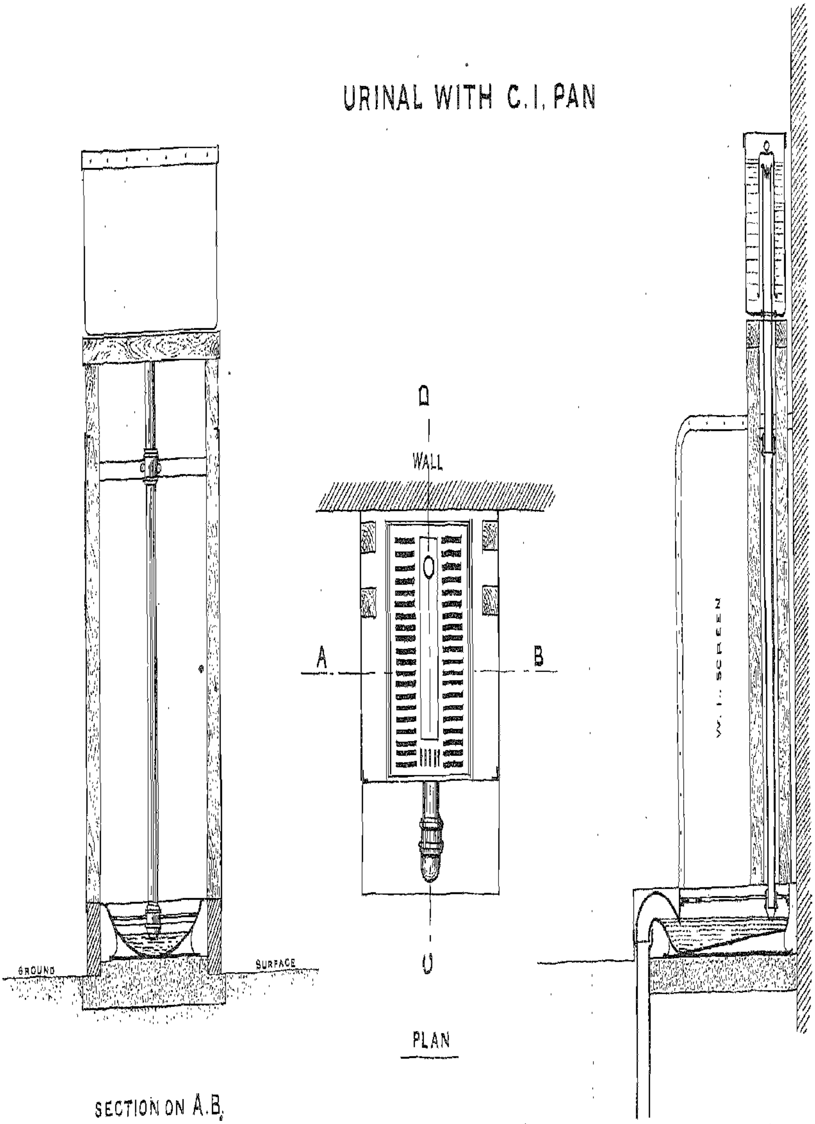


PLATE 22

URINAL WITH C.I. PAN

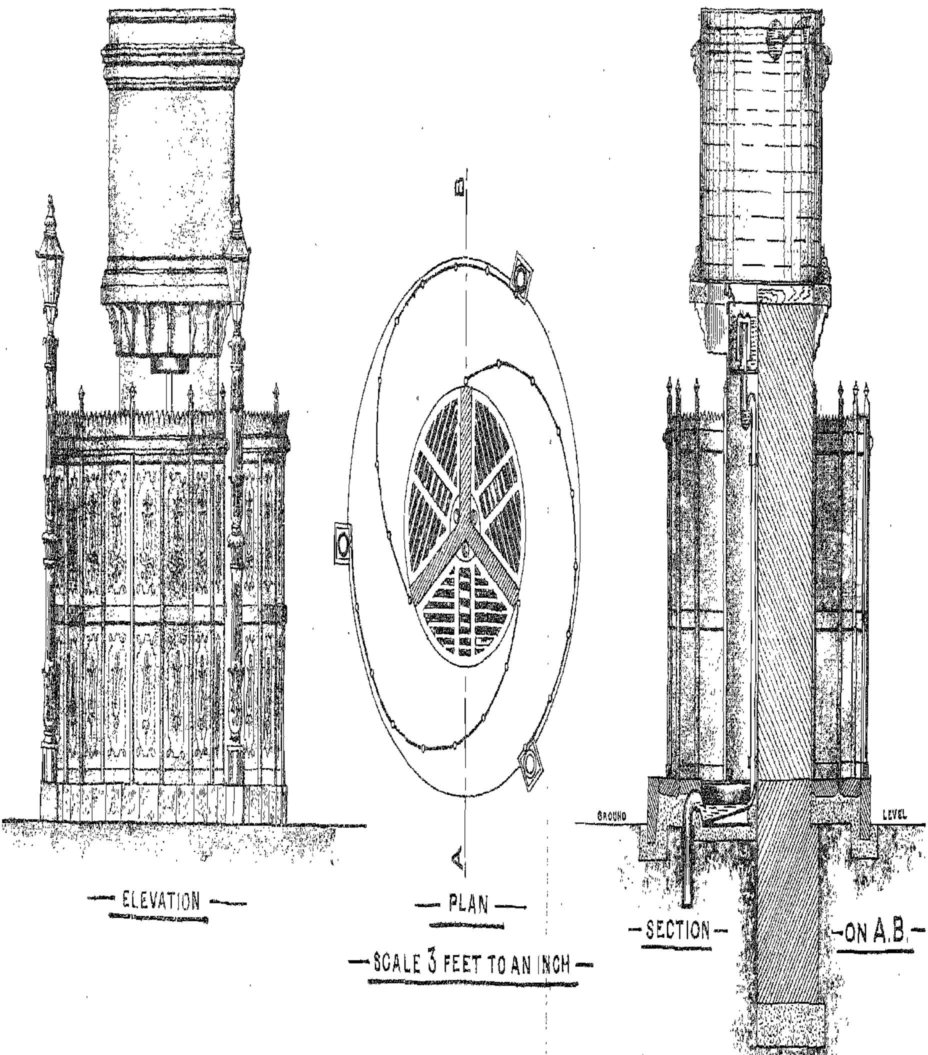


SECTION ON A.B.

SECTION ON C.D.

SCALE $\frac{1}{2}$ INCH TO ONE FOOT

— CIRCULAR URINAL —



— ELEVATION —

— PLAN —

— SECTION — — ON A.B. —

— SCALE 3 FEET TO AN INCH —

is without any kind of trap. When this pattern of trough latrine was first tried, it was found that the users got splashed, and for this reason natives had a great objection to it. The trouble was, however, got over by hanging a small iron plate under the pan and just above the normal level of the water in the trough, so that, when the flushing tank discharged, this plate became completely covered and cleansed of any solid matter on it. This arrangement has been found satisfactory and has removed the original objection. These latrines are simple and economical and, for public use among the poor and more uneducated classes, are perhaps the best.

Urinals.—As in latrines so in urinals great strides have been made in Bombay towards securing greater sanitary efficiency. One of the earliest urinals constructed in Bombay, and one that was in use for many years, is shown in Plate 22. This urinal is for the most part constructed of iron and may be of any length and of various shapes. The compartments may be divided by wrought-iron partitions 5 feet in height. The pan of the urinal, which can be continuous from end to end, holds water which at the greatest depth is 6 inches. The users squat, as is the distinctive custom in India, on slightly raised iron steps, and the urinal is flushed from an automatic over-head tank of a sufficient capacity at each flush to displace the whole of the standing water in the urinal.

Plate 23 shows a circular urinal on this system.

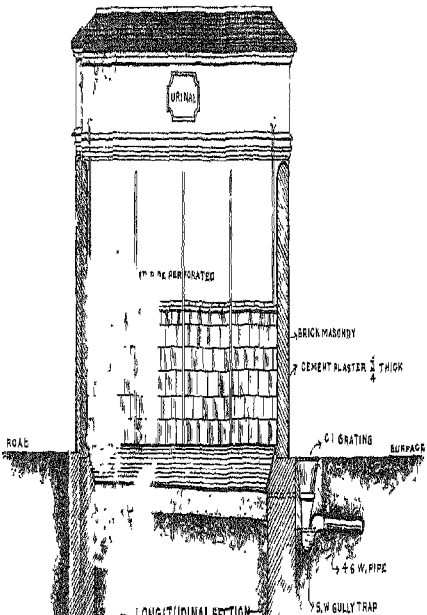
This type of urinal was never quite satisfactory, as being almost entirely constructed of iron, it rusted rapidly, while it was not possible to keep it in a sanitary condition, as it lent itself to misuse as a latrine for which it was manifestly not suitable. These urinals were almost the

first public urinals constructed in Bombay, but they have been nearly all replaced with the new pattern hereinafter referred to.

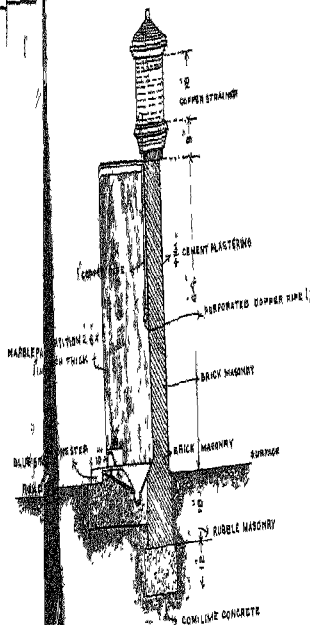
The newest form of urinal used in Bombay is shown in Plate 24. It is a trough pattern and was designed by the Author in conjunction with Col. T. S. Weir, I.M.S., late Health Officer to the Bombay Corporation, and is known as the "Combined Constant Flushing Urinal." The trough is of white porcelain, and the front is lined with glazed tiles to a height of 3 feet 6 inches or as far as the copper flushing pipe. The urinal is flushed continuously from a tank placed on the top of the structure and extending nearly its whole length. The size of the water-supply tank may be calculated on the basis of 50 gallons per division per day, so that, if the urinal has four divisions, the tank should hold 200 gallons. All parts of the trough and the front wall continually receive a small stream of water. The partition walls, which are marble slabs, are 2 feet 3 inches apart and 6 feet in height. The contents of the urinal discharge through a trap placed at the lower end and connected with the sewer. The name "Combined" was given to this urinal, because of the great advantage of its being able to be used sanitarily either in a standing or squatting position, and is thus suitable for all races. From time to time the trough and the front require to be cleaned with a dilute solution of sulphuric acid in order to remove stains, which after a while discolour the glazed surfaces. The urinal has been a success and is undoubtedly the most sanitary for general purposes yet constructed in Bombay. Many have been built in the City in various positions, and Plate 25 shews one placed in an angle of a wall.

DETAILS OF COMBINED CONSTANT FLUSHING URINAL

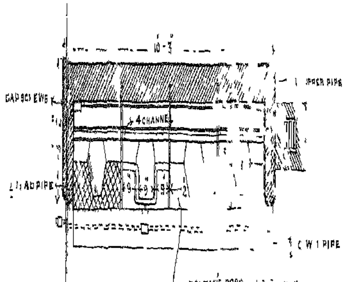
SCALE 4 FEET TO 1 INCH



— LONGITUDINAL SECTION —



— CROSS SECTION —



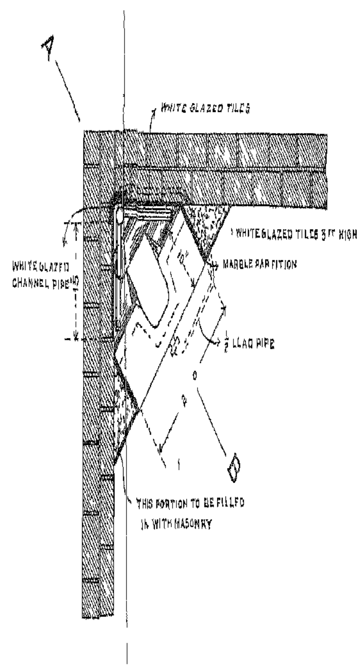
— PLAN —

COMBINED CONSTANT FLUSHING URINAL

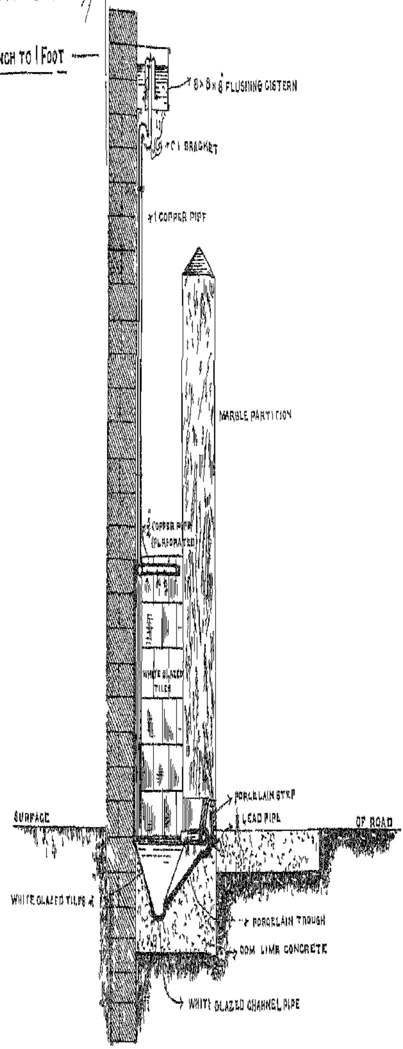
(PLACED IN A CORNER)

SCALE ½" INCH TO 1 FOOT

PLATE 25

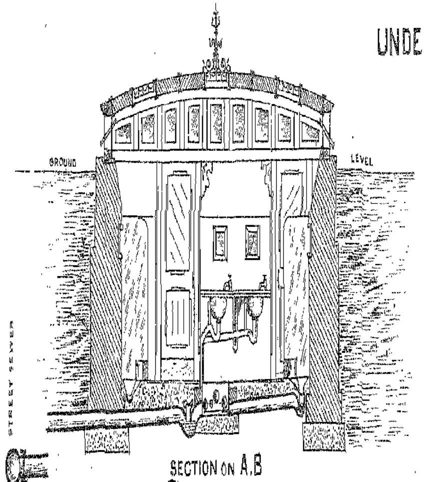


PLAN

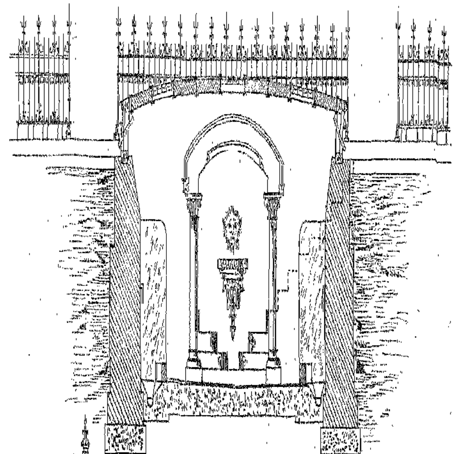


VERTICAL SECTION ON LINE A.B.

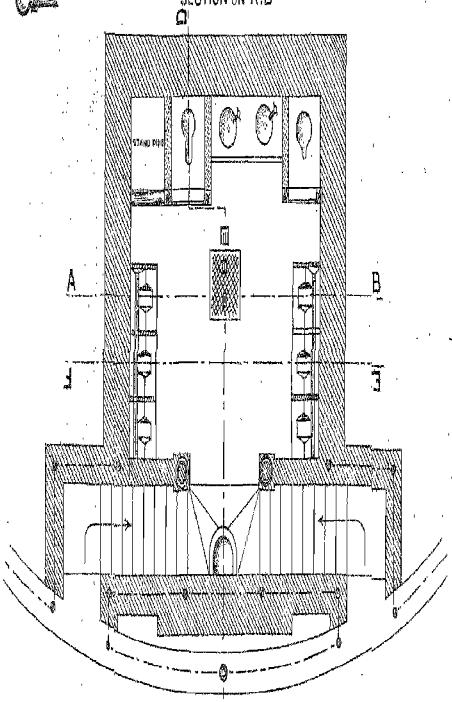
UNDERGROUND PUBLIC CONVENIENCES



SECTION ON A.B

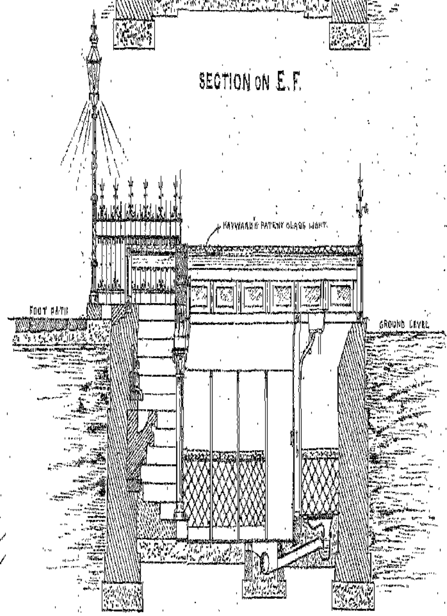


SECTION ON E.F.



PLAN

C



SECTION ON C.D.

SCALE 6 FEET TO AN INCH

The cost of such a urinal is somewhat greater than that of the old cast-iron pattern, but being a combined urinal its advantages greatly overweigh the slight extra expense.

The use of continuous flushing for urinals has of late to a large extent been discontinued in England and periodic flushing substituted, because of the large amount of water used by the former; but in a country like India it is not advisable to economise water in a public convenience.

Plate 26 gives a useful design for an underground public convenience after the pattern used in London. The depth of the structure underground from the surface of the road to the floor is 7 feet, it b ing also 1 foot 6 inches above the surface of the groun , but the underground depth can, if necessary, be greater, the level of the connecting sewer governing that point. The place is lighted by means of Hayward's patent glass lights inserted in the roof. Steps are provided on one side for the entrance to and the exit from the structure. It contains two separate water closets, one for Europeans and the other for Natives, and two hand washing basins. Conveniently situated and next to the native water-closet is a washing place fitted with a stand pipe for obtaining water for ablutionary purposes. There are also provided six Combined Constant Flushing Urinals, three on each side and a small ornamental drinking fountain is placed at the bottom of the stairs leading to and from the structure. The whole installation is complete both for Europeans and Natives, and should prove to be a very useful convenience in the business part of a large town. For the use of a water-closet a small charge could be levied to

meet the wages of the attendant in charge. Some artificial method of ventilation is almost indispensable in an Indian city for such a structure, and possibly the simplest would be by means of shafts topped with revolving cowls.

Plate 27 shews a useful and complete above-ground installation of public latrines, urinals, and washing places with a well-paved and drained enclosure. This and similar installations have been constructed and are in use in Bombay, and have all the necessary conveniences for both sexes. A partition divides the latrine into two parts for the different sexes, each side being supplied with its own washing place. The latrines themselves are on the newest pattern as shewn in Plate 20.

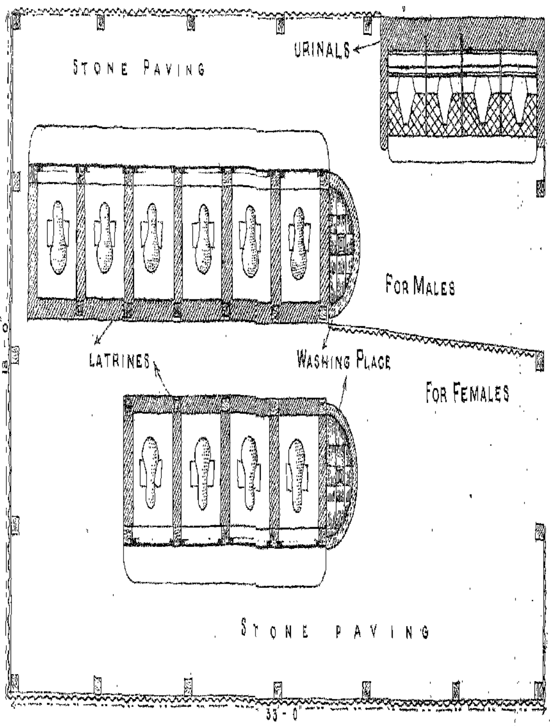
Such an expensive class of latrine for use in all parts of the city is not recommended. In crowded and poor districts a trough pattern would be preferable both on account of its lesser cost and because of its greater sanitariness under careless usage.

Discretion is necessary in deciding on a pattern and size of public latrines, as certain classes of people will not use them under any circumstances, and certain classes are not yet sufficiently educated to use them properly.

Night-soil Depôts.—In no Indian city has the introduction of water-closets in private houses yet become universal or even common. In Bombay, in by far the larger portion of the city, night-soil is removed by hand either in tarred baskets or in carts into which the baskets are emptied and taken to the nearest night-soil depôt and discharged into a sewer.

Plate 28 shews a complete night-soil depôt as now used in Bombay. The carts are backed across the set stone paving to the stops until the discharge pipe is over

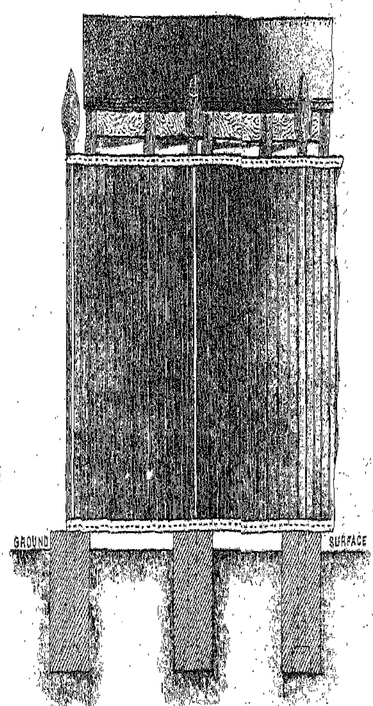
A COMPLETE INSTALLATION OF PUBLIC CONVENIENCE



— PLAN —

— SCALE OF 5 FEET TO AN INCH —

— SIDE ELEVATION —



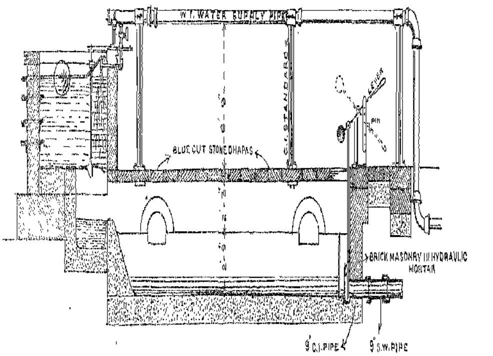
— SCALE OF 4 FEET TO AN INCH —

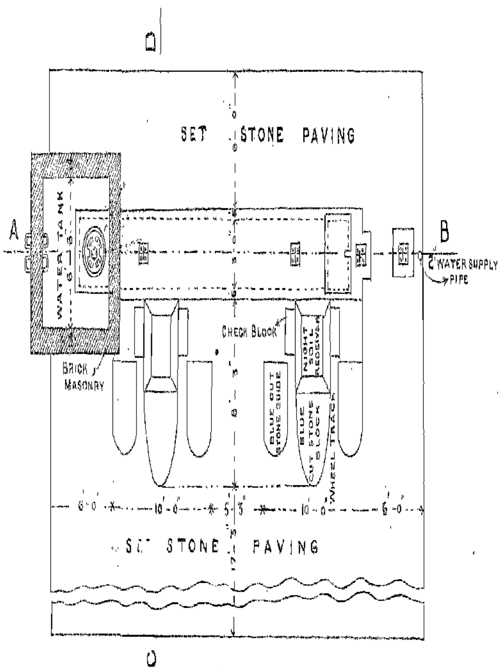
PLATE 28

NIGHT SOIL DEPÔT

SCALE OF 8 FEET TO AN INCH

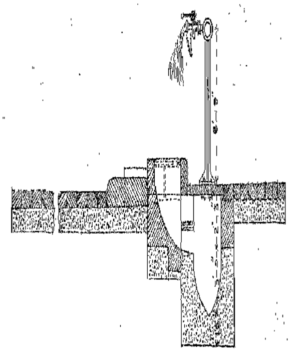
SECTION ON AB





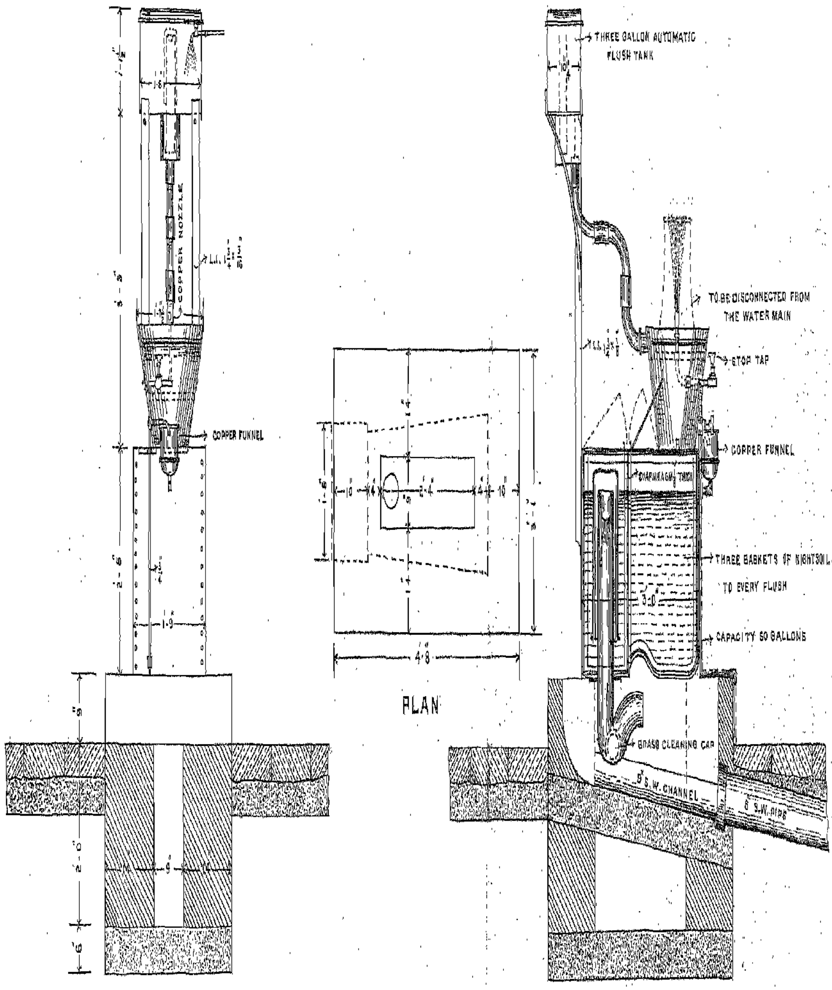
PLAN

SECTION ON CD



EXCRETA DISPOSER

SCALE 2 FEET TO AN INCH



the opening of the hopper. In the latter is fixed a grating, the bars of which are set close enough to prevent road metal and tiles from passing through them. The hopper discharges into a central tank, called the night-soil tank, with which is connected a masonry water tank, provided for flushing purposes. Running the whole length and about 7 feet high above the night-soil tank is fixed a water-supply pipe with two branches, one over each hopper for flushing it and its surroundings and cleansing the cart if necessary. An ample supply of water is an absolute necessity in a night-soil depôt of this description, for it is requisite to thoroughly dilute with water the contents of a night-soil cart before discharging them into the sewer. The final discharge from the night-soil tank into the sewer is arranged by opening, by means of a lever, a penstock fixed at the lower end of the tank.

Plate 29 shews a useful night-soil depôt of small size designed by the Author several years ago, used exclusively for the emptying of baskets, and time and experience have proved the suitability of this appliance. It consists of a tank holding 50 gallons of water and divided into two compartments. The smaller compartment is fitted with an ordinary annular siphon, the inner leg of which is trapped at the bottom, and discharges into a branch drain in connection with the main sewer. Fixed on the top of the other compartment of the tank is a funnel of a size sufficient to take at its top a night-soil basket, which being inverted rests on a ledge on the inside of the funnel. An automatic three-gallon flush tank is connected to a flushing rim at the top of the funnel, and serves to keep the funnel clear of night-soil. The basket after being emptied through the funnel into the tank is flushed by means of

the upright water pipe, which shoots the water jet into the basket, thoroughly scouring its sides. The main tank is designed to dispose of three baskets of night-soil for every discharge of 50 gallons of water. Great care must be taken to see that the water pipe supplying the jet for cleansing the basket is so cut off from the water main as to prevent any possibility of it in any way becoming contaminated by night-soil. This should be preferably done by fixing a supplementary tank at such a height as to give the necessary pressure to the jet for cleaning purposes.

Washing Places.—Plate 30, Fig. 1, shews a design of a public washing place. Such an installation should be paved with stone, laid on concrete and jointed with cement. The paved space is usually divided by a central wall into two compartments, one side being reserved for males and the other for females. On each side of the wall is fixed a water-supply pipe with taps at convenient distances, an open channel being constructed at the bottom of the central wall for the discharge of the water, which drains at the lower end into a trap on a branch pipe drain connected with the nearest sewer ; the paving on both sides is sloped towards this open channel. Around the whole of the outside of the paving should be fixed a line of curb stones rising 4 inches above the pavement.

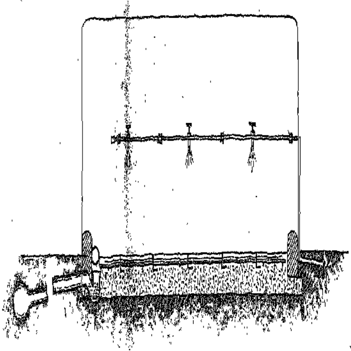
Cab Stands.—Plate 30, Fig. 2, shews the construction of a cab stand for a public street. The pavement in this case should be always of set stones. The stand should be 6 feet in width with a slope of 2 inches from either side towards the centre. In the centre a cast-iron trough, 4½ inches deep by 5 inches wide, is fixed, running the whole length of the stand and having an opening at the

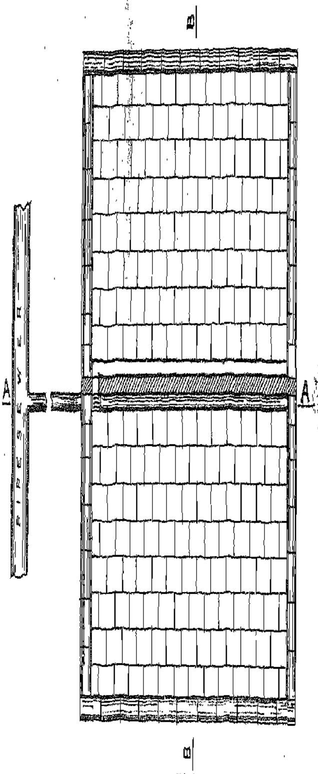
PLATE 30

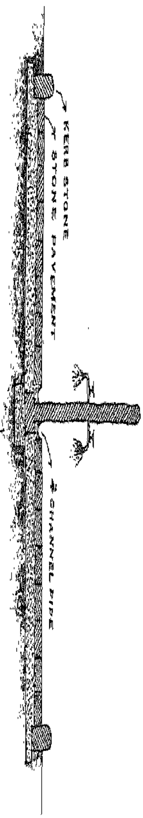
Washing-Place

Scale 4 Feet to an Inch

Section at A.A.







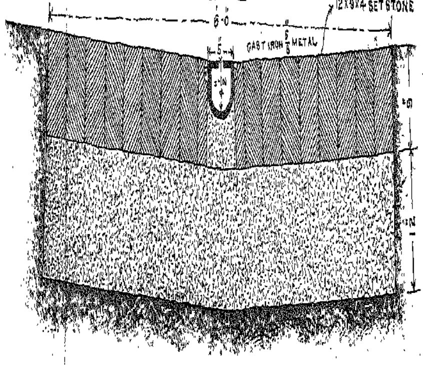
SECTION AT B.B

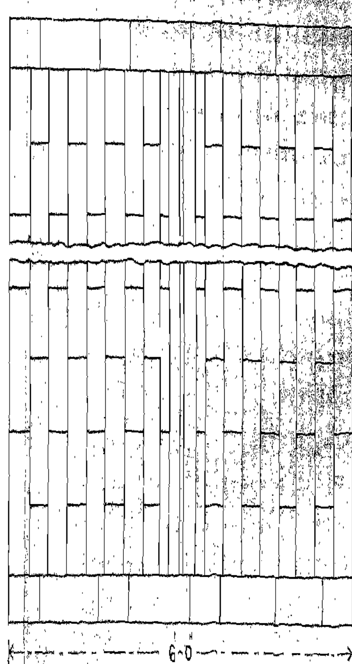
PLAN

Cab-Stand

1/16 Full Size

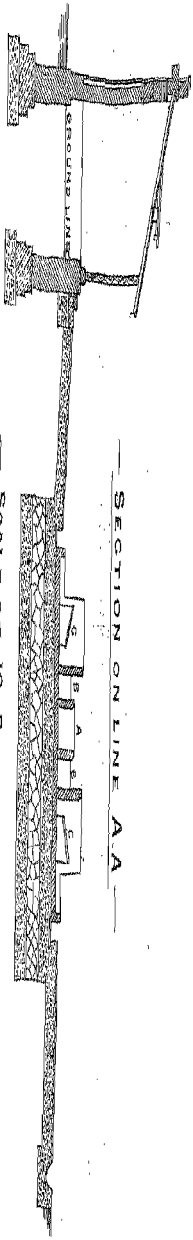
Section





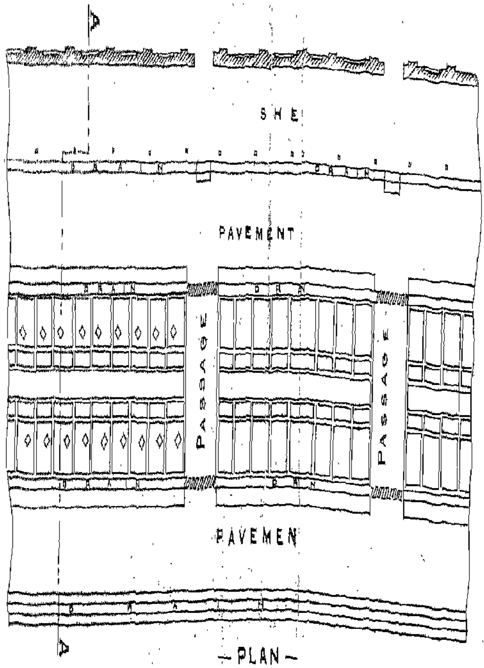
PLAN

— DHOBI GHI —



— SECTION ON LINE A A —

SCALE OF 10 FEET TO AN INCH.



— PLAN —

— SCALE OF 20 FEET TO INCH. —

top 1 inch wide to admit drainage. This metal trough should have a slope of 1 in 100 to one end and be there connected by a trap and a branch pipe to the nearest sewer. Cab stands may be of any length to suit circumstances, but, if of greater length than about 200 feet, should be drained in sections.

Public Dhobi Ghat.—Plate 31 gives a drawing of a public Dhobi Ghat or place for washing clothes. Such a Dhobi Ghat can be made of any size to accommodate any number of dhobis or washermen. The central channel, marked **A** in the section, is a general water tank fitted with a ball-cock to maintain the level of the water. **B**, **B**, are small tanks opposite each compartment, from which the dhobi obtains the necessary water for washing purposes and which are filled by hand from the general water tank **A**. The stone, on which the clothes are beaten, is marked **C**, the covered shed being for the bhutti or boiler for boiling the clothes. The whole of the Ghat is constructed of stone paving set on concrete and jointed with cement. A small charge per month is made for the use of each compartment. A Dhobi Ghat, as above described, is a desirable institution in every Indian town which has a water-supply and a drainage system, in order that all public places, where clothes are washed, may be brought under supervision and conducted with due regard to cleanliness and proper drainage. The filthy conditions under which clothes are generally washed where no supervision is exercised and no suitable accommodation provided, cannot fail to be a fruitful source of danger to public health.

CHAPTER IV.

House Connections.—The general principles of house connections used in Europe require considerable modification before they can be adapted to the peculiar conditions which obtain in India. It is desirable, therefore, before describing the best system of house drainage connections for Eastern cities, to give a short description of a typical house and the manner in which the towns are often laid out.

Large buildings abound in which it is not unusual to find as many as twenty rooms on each floor, each occupied by a different tenant or tenants, and in each room a "nahani" or washing place, known in some localities as a "mori." In the bazaars and other thickly populated parts, these houses are often only separated by narrow passages or gullies, which are provided for drainage purposes and for obtaining access to the privies. The streets are generally narrow and badly paved, and it will be obvious that to keep such localities healthy and sanitary is no light task. Refuse and rubbish are generally thrown out of the nearest window, as that entails the minimum of trouble. The consequence of this practice, combined with the fact that the washing place, which is in nearly every room, is by no means always confined to the purpose for which it is provided, is that the gullies between the houses soon get into a filthy condition and a large staff of scavengers have to be kept up by the Municipal authorities to clean and flush them.

The first method adopted for dealing with these gullies in Bombay was as follows :—

> A 6-inch stoneware pipe drain was laid in the gully and disconnected from the sewer in the street by means of a running siphon. Each waste water pipe discharged into a trap placed at the foot of it and connected with the 6-inch pipe drain by a 4-inch pipe. Traps connected with the same pipe drain were also provided for the privy sullage 2 and a 2½ inch cast-iron pipe fixed at the higher end of the 6-inch pipe drain ventilated the same. The whole surface of the gully was finished either with stone paving or with cement plaster.

This system was found to be unsatisfactory ; the traps and pipe drains quickly choked with vegetable rubbish or refuse from the nahanis, which resulted in the paving being flooded and the general condition of things being no better than if no pipe drain existed. In time, owing to constant sweeping and flushing, the stones forming the pavement of the gully became uneven, the joints opened and the sewage and sullage soaked into the foundations of the houses. For such a class of property situate in the heart of a thickly populated city, it was necessary, therefore, to design some better system, which would, as far as possible, be free from the above disadvantages.

The system now prevalent, and one that has given undoubted satisfaction, is to construct open branch drains in all such gullies. These open branch drains, which are more fully described hereafter, are 4 inches wide by 6 inches to 8 inches in depth, and are constructed at a gradient of not less than 1 in 100. They have the great

advantage of being easily swept clean, and, though rubbish may choke them, it can only do so temporarily.

It is most essential that proper care should be taken to prevent gas and foul air from the sewer entering the houses. This is more important here than in Europe, not only on account of the greater quantity of the sewer gas generated, but also because the tenants of the house often live, eat and sleep in the room, where the nahani with its pipe connection is situated.

The depth of seal in any trap for house drains in India should never be less than 3 inches. Traps can never be absolutely relied upon, and should be regarded more in the light of a necessary evil, which it seems impossible at present to improve upon. They fail from various causes, such as sewer gas forcing its way through them under pressure; evaporation of water in the trap; siphonage due to a piece of rag or paper being caught part way; and from the water being removed on account of a partial vacuum due to a sudden discharge of water down the pipe connected with them.

Under any circumstances, house connections are an expensive item, and they should therefore be kept as simple as possible consistent with efficiency.

The following few rules may be considered to be applicable to general house-connection work in India, when for any reasons it is preferable to use pipe drains :—

The branch pipe drain connecting a house with the street sewer should be always of well burnt stoneware and of a minimum size of 4 inches in diameter. The gradients of such pipes should not be less than 1 in 50.

All such pipe drains should be laid in straight lines with true gradients from one inspection chamber to the other. An inspection chamber should be constructed at every angle in the drain and on long straight lengths, at distances of 100 feet.

All pipes should first be laid and fitted dry, previous to any jointing being done. All joints should be caulked with tarred gasket in one length, sufficiently long to entirely surround the spigot end of the pipe, the gasket being driven in as far as possible into the joint. The joint should then be wetted, and neat Portland cement forced in until the whole space around the spigot is quite full, the jointing being completed with a splayed fillet of pure cement being laid all round it.

Before being covered the joints of the pipe drain should be tested for water tightness by closing the lower end of the length of pipes and filling it with water to the level of 6 inches above the top of the highest pipe. If the level of the water does not fall within one hour, the joints may be considered satisfactory.

All inlets to pipe drains should be trapped with the exception of those used for ventilation.

The higher end of the pipe drain should be finished with a quadrant bend to receive a ventilating pipe, or, preferably, an inspection chamber should be constructed into which the bend should be built just beneath the cover.

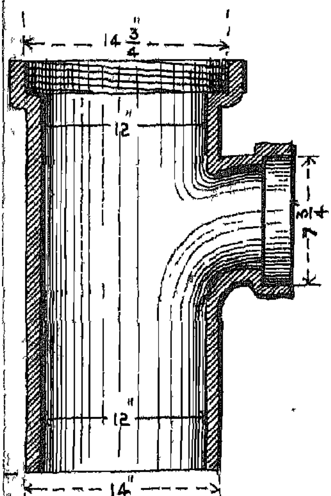
Excessive and unnecessary depth of excavation should be avoided.

In the event of a satisfactory gradient not being obtainable, arrangements for sufficient flushing to produce a self-cleansing velocity must be provided.

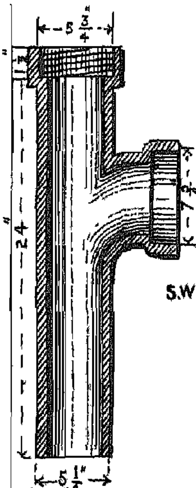
Plates 32 and 33 show respectively the class of stoneware and cast-iron pipes and fittings used in house-connection works in Bombay. It has been the practice to use 6-inch pipes for all branch drains, except those of very short lengths. This size is in many cases theoretically too large for the maximum amount of sewage which the pipes will ever be called upon to discharge, but is adopted for the reason that so much solid matter in the way of sand, ashes, and vegetable refuse is discharged into the branch drains that pipes of less diameter would constantly become choked.

The intercepting sewer trap shown in Plate 32 is one of the most necessary and useful traps in use, and, whether the open or closed system of pipe drains is adopted, a house, where this is not provided, cannot be considered to be properly drained. It is usually fixed in an inspection chamber built at the lower end of the house pipe drain, of a size sufficient to allow of a cleaning rod being easily manipulated. It is provided with a cleaning eye, by means of which any obstruction in the drain between the trap and the public sewer in the street can be removed without disturbing the surface of the road.

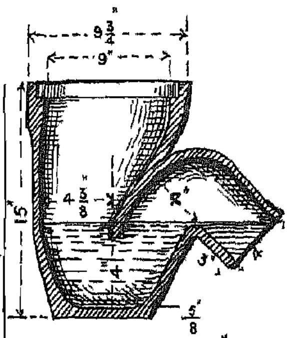
There are various kinds of junction pipes shown in Plate 32. Such junctions should either be quadrant, or oblique and the use of T Junctions avoided, because these direct the flow of sewage at right angles, instead of obliquely in the direction of the flow of sewage in the main pipe.



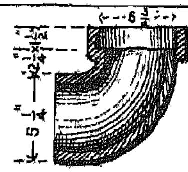
12" X 6" STONEWARE QUADRANT JUNCTION



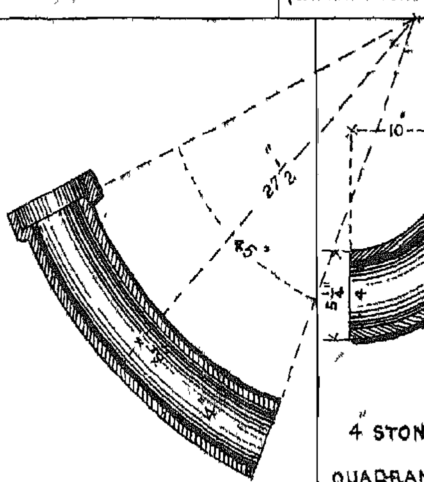
4" X 4" STONEWARE QUADRANT JUNCTION



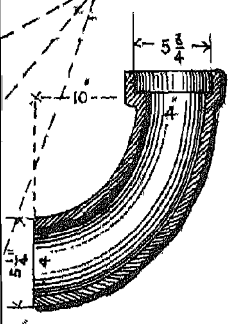
S.W. GULLY TRAP 9" X 9" WITH 4" OUTLET



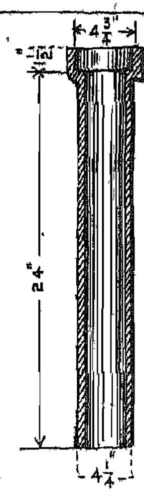
4" STONEWARE KNUCKLE BEND



4" STONEWARE SEGMENTAL BEND



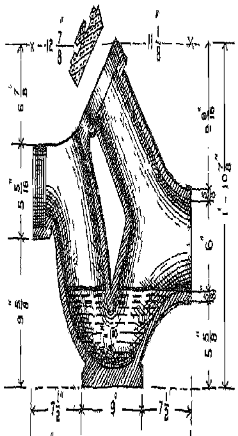
4" STONE WARE QUADRANT BEND



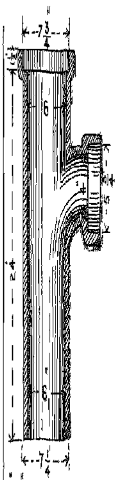
3" STONEWARE PIPE

DIMENSIONED SKETCHES OF THE PIPES FITTINGS &c.

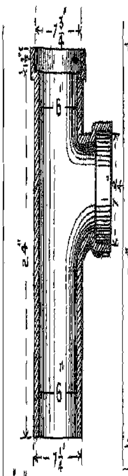
SCALE 1 INCH TO 1 FOOT



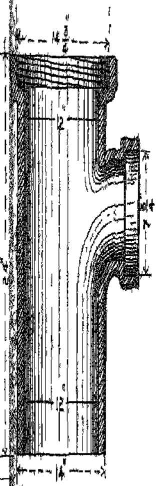
6" INTERCEPTING SEWER TRAP



6"X4" STONEWARE QUADRANT JUNCTION

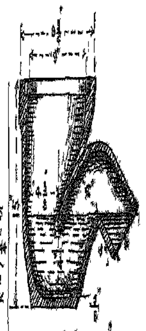


6"X6" STONEWARE QUADRANT JUNCTION

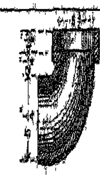


12X6 STONEWARE QUADRANT JUNCTION

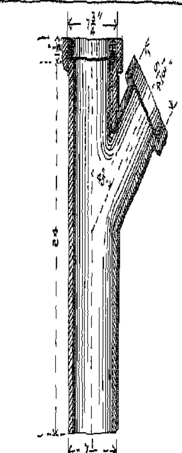
4 X 4 STONEWARE QUADRANT JUNCTION



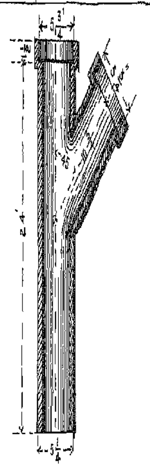
S.W. GULLY TRAP 9X9 WITH 4" OUTLET



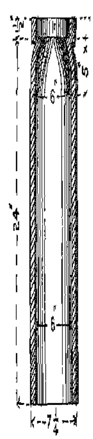
4" STONEWARE KNUCKLE BEND



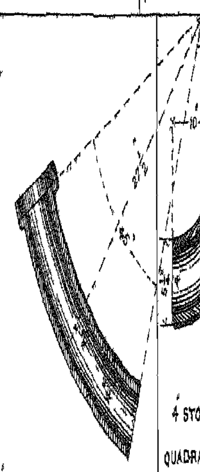
6"X4" SW. OBLIQUE JUNCTION



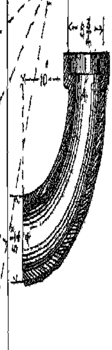
4"X4" STONEWARE OBLIQUE JUNCTION



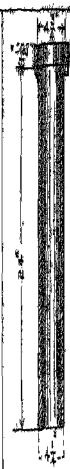
6"X4" STONEWARE TAPER PIECE



4" STONEWARE SEGMENTAL BEND



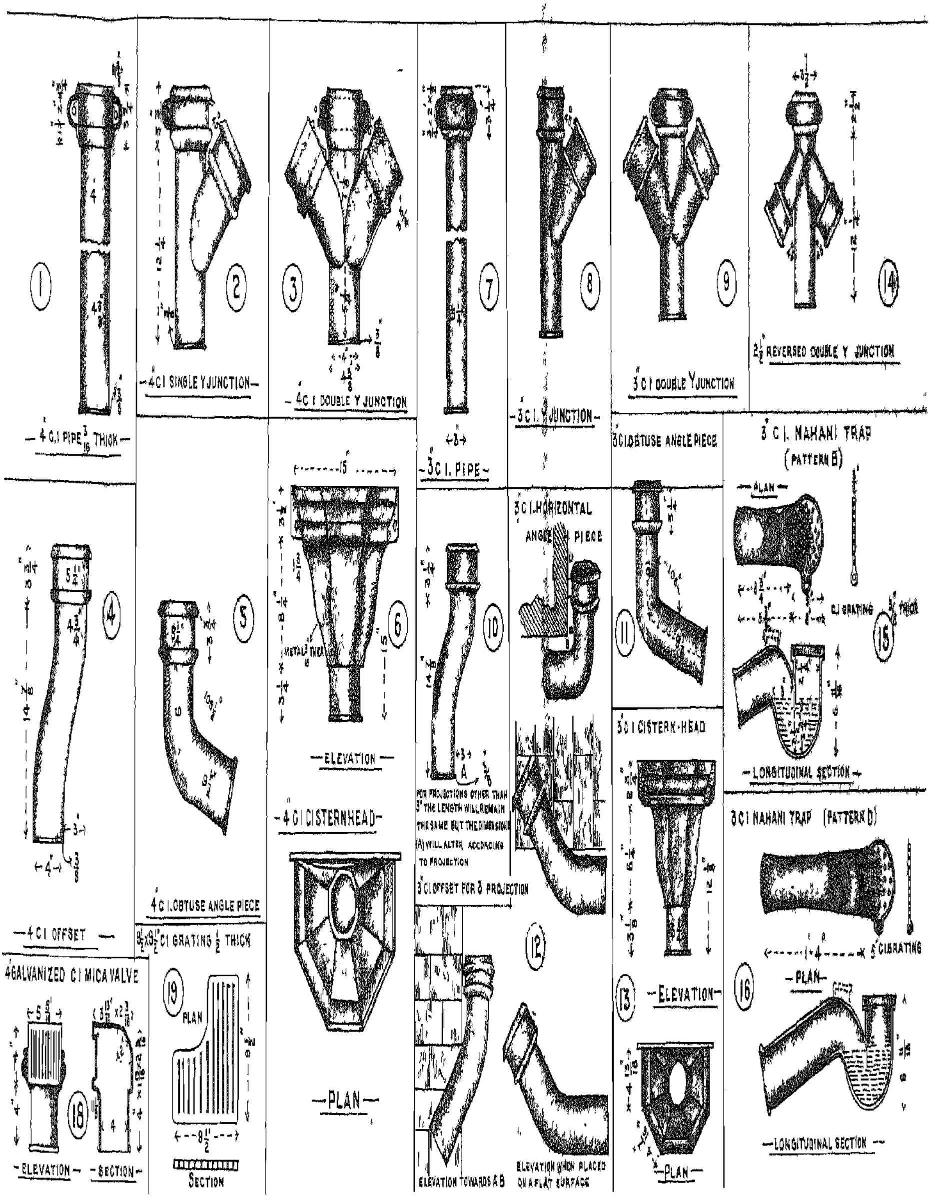
4" STONE WARE QUADRANT BEND



3" STONEWARE PIPE

DIMENSIONED SKETCHES OF THE PIPE FITTINGS &c

SCALE 1" INCH TO 1 FOOT



The 6 inches by 6 inches stoneware trap with a 4-inch outlet is a common and useful fitting; and, where a closed pipe drain is the main conduit for conveying the house sullage to the sewer, one should always be inserted at the bottom of every waste water down-take pipe to receive the sullage from nahanis and washing places.

All waste water pipes should be 3 inches in diameter and the joints should be made air-tight with a mixture composed of Portland cement, boiled-oil, and chopped hemp, a ring of tarred gasket being first inserted into the joint.

Soil pipes should be universally 4 inches in diameter. The thickness of waste water pipes and soil pipes will vary, but it should not be less than 1/8th of an inch in the case of the former and 3/16ths of an inch in that of the latter.

The trap, shown in Plate 33, is inserted in a nahani to prevent the foul air in the down-take pipe from entering the building.

All cast-iron pipes and fittings, used for house drainage purposes, should be coated with Dr. Angus Smith's solution before use.

The following is the method by which pipes are coated with this solution :—

A tank or bath required for the above process should be of sufficient capacity to allow of the complete immersion of the largest size of pipe to be coated, and should be externally fired in such a manner that the heat from the furnace is evenly distributed over the bottom of the tank.

The coating mixture is made from coal pitch, distilled until all the naptha is removed, or what is known as Burgundy pitch, and 6 per cent. by weight of boiled linseed oil.

Pitch, which becomes hard and brittle when cold, should be rejected.

The pipes, which must be thoroughly clean and free from rust, are immersed in the bath, when its temperature has risen to 300° F., and are kept there until they have attained the same temperature ; after removal they should be placed on end to drain.

The bath requires careful attention and should be kept, as far as possible, at an even temperature. Overheating will result in the contents boiling over, and insufficient heat will produce too thick a coating.

The mixture will after long use become thick, when a little more oil may be added, but when too thick to produce an even and thin coating, it should be removed and fresh materials substituted. Coal tar must on no account be used for thinning, as it will cause the bath to foam.

All inspection chambers should be constructed of $4\frac{1}{2}$ inch brick-work, internally plastered with a half inch coating of cement and sand (1 to 1). At the bottom of the chamber a channel with a half-round pipe of the width and the full depth of the pipe drain should be constructed. The chamber should be covered with a cast-iron air-tight frame and cover as shown in Fig. 23.

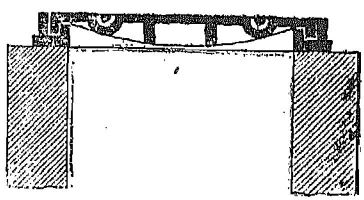


FIG 23

The experience after several years' trial in Bombay is that the portion of the drain for the conveyance of the house sullage, which is within the house premises, is better open than closed. This conclusion has been arrived

at on account of the liability of the closed drain to chokage due to the large amount of all kinds of solid matter, deliberately or carelessly put into the drain by the inmates of houses.

The width of the gullies between houses varies from 1 foot to 3 feet or more. In the case of narrow gullies, the open drain may be constructed in the centre, any rain water falling on the gully being allowed to flow away with the sullage. In wider gullies the drain should be constructed on one side, as shown in Fig. 24, and the storm-water channel on the other. In the case where two open drains are constructed, one on each side, the storm-water channel should be laid in the centre.

The class of open drain found most satisfactory is that shown in Fig. 24. It may be constructed either in the centre or on one side of the house-gully. The invert is lined with 4-inch channel pipes and the remainder, which is of brickwork, is rendered with a half inch coating of cement and sand (1 to 1).

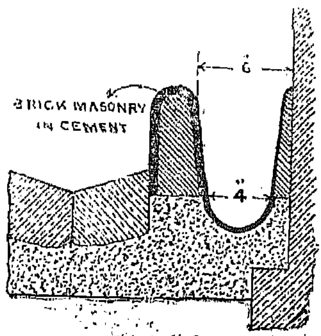


FIG 24

The drain is very easily flushed and kept clean and

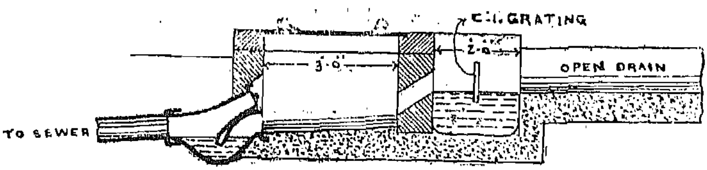
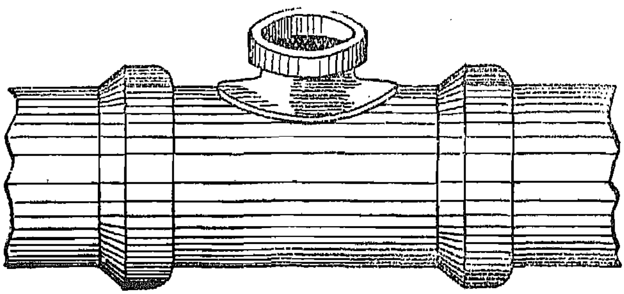


FIG 25

at the end and between it and the inspection chamber, which contains the intercepting sewer trap, is constructed

a small silt chamber with a cast-iron grating as shown in Fig. 25. If these small chambers are regularly emptied, the success of the open drain is assured. The minimum gradient at which these open drains should be constructed is 1 in 100.

The practice in Bombay is for the houseowner to construct the house drain up to the boundary of his property and also the inspection chamber, with the intercepting sewer trap and the ventilating pipe on the street end of the drain, and for the Municipal Corporation to lay the connecting closed drain in the public



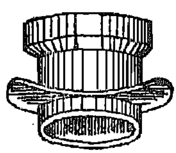


FIG 26

street. The "street connection," as this connecting drain is called, should in all cases consist of a 6-inch pipe drain, which is connected to the street sewer by means of a junction pipe, or in the event of there being no junction pipe, by means of a saddle piece as shown in Fig. 26.

An open drain is not applicable to any house where water closets are in use. For such houses, a closed drain must be laid for both sullage and fœcal matter as before

described ; or an open drain should be constructed for the sullage and a closed one for fœcal matter.

It will be many years before the use of water closets in any Indian City will become general. The habits of the people are in many ways not suited to them, and caste prejudices often interpose. Wherever practicable, and in the case of houses occupied by the higher class of Natives and Europeans, water closets are desirable. Various kinds of soil pans for water closets suitable for Natives are now made, and a more detailed description of those patterns has been given in Chapter III. For Europeans, the class of soil pans in use in England is also suitable here, but preference should always be given to a wash-down pattern, as there is less area to foul. All water closets, whether for Natives or Europeans, should be flushed by means of a three-gallon flush tank, a water-supply tank being provided in a suitable position.

In hotels, clubs, and other institutions, where hand basins are provided and urinals, apart from water closets, are generally considered necessary, there is practically no departure made in either the construction or method of drainage from the ordinary English practice. In buildings set apart for the sole use of Europeans, urinal basins are generally used, and for Natives the pattern shown in Plate 20 will be found perfectly satisfactory. Such appliances should always be placed against an exterior wall, so that a length of pipe drain under the floor of the building may be avoided. Efficient flushing appliances are essential and, of course, a reliable and ample water supply is imperative. Any thing more offensive and dangerous than a water closet without water in a hot tropical weather, it would be hardly possible to imagine.

The building bye-laws in Bombay now specify that all water closets and privies should be cut-off from any living room by at least a three-feet air space on all sides, but this rule has only come into force in recent years, and in the majority of houses in the City, the privies are not detached in any way from the main building, but on the other hand are often built against an interior wall in a convenient position. Plate 34 shows in detail the class of privy to be found in most Indian houses. Such a privy from a sanitary point of view must be considered insanitary. Looking, however, to the present sanitary education of the people, it is probably the best arrangement that can be provided when a water closet is out of place, and it falls in with the caste prejudices of the people, who prefer it to all other arrangements. The sloping part of the privy, which receives the night soil, and the sides should preferably be lined with plate glass, as this material is not only incorrodible but fœcal matter does not readily cling to its surface.

The privies are usually connected with a shaft, constructed of brick-masonry plastered with lime or cement, and of an internal measurement of 18 inches by 18 inches. But latterly these masonry shafts have been replaced by 6-inch stoneware pipes,—an undoubted improvement. After a time, these shafts must naturally get coated with fœcal matter and become insanitary as they have no flushing arrangements, and their state of cleanliness depends solely on the amount of water thrown down them by hand through the privies. The shaft discharges its contents into a basket as previously described.

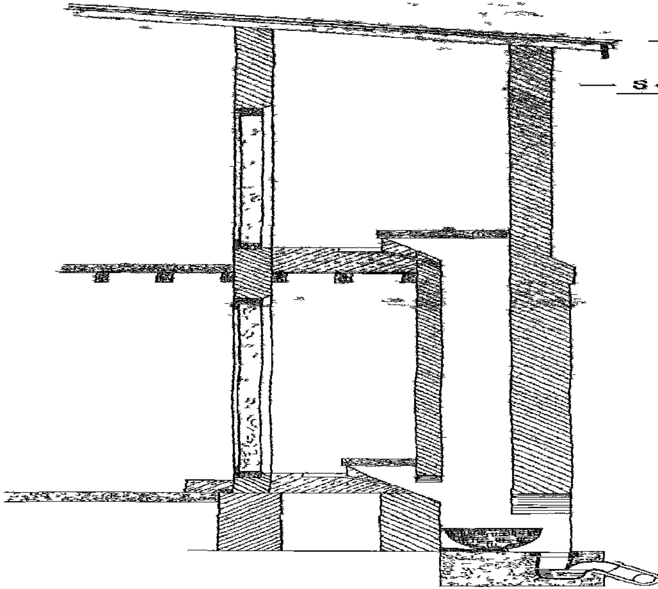
Some years ago, the Author designed and carried out an Intermediate System to be used in connection with

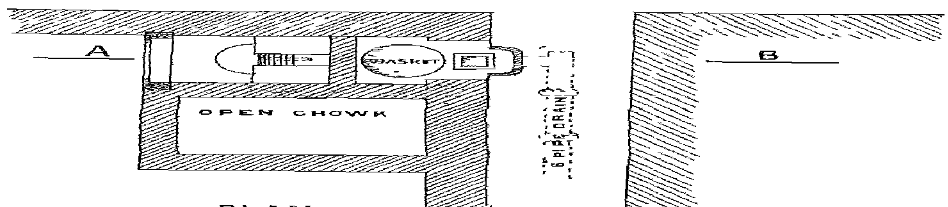
PLATE 34

INDIAN PRIVY

SCALE 4 FEET TO AN INCH

SECTION ON A.B





PLAN

PLATE 54

INDIAN PRIVY

SCALE 4 FEET TO AN INCH

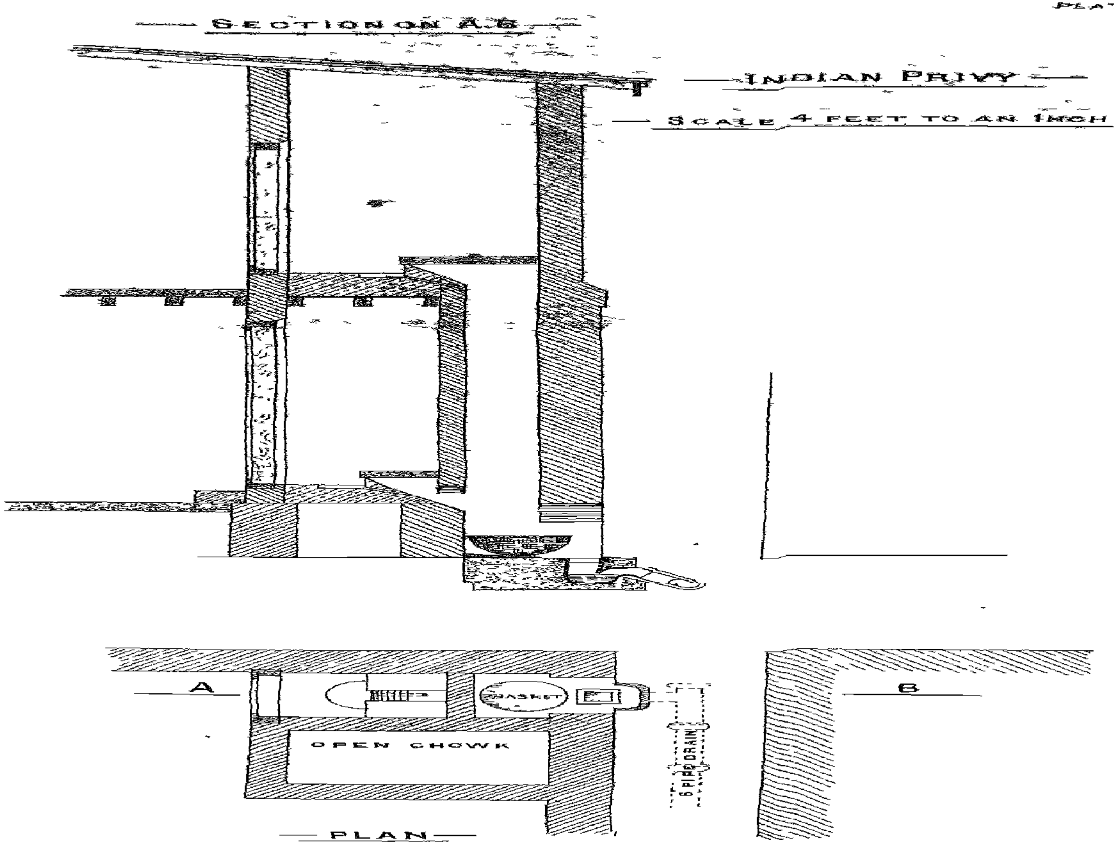
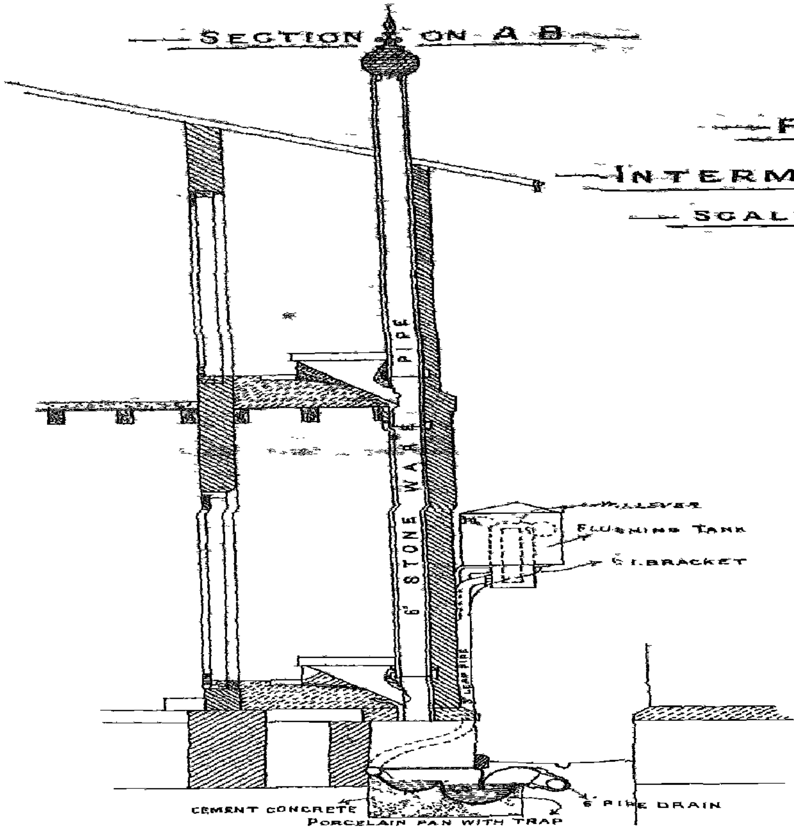


Plate 35

Privy
on
Intermediate System
Scale 4 feet to inch

Section on A B



privies. This consisted of the substitution for the usual basket of a stoneware soil pan at the bottom of the shaft. Into this pan everything from the privy was discharged. An automatic flushing tank was fixed on the wall outside the privy, containing from 10 to 20 gallons of water according to the number of privy seats. It was connected with the soil pan, and on the water being discharged the contents were flushed through a trap into a branch drain connected with the sewer. The soil pan was made of such a shape that solid matter such as stones, tiles and rags were retained in it, and the sole work of the sweeper was to remove these materials, everything soluble being flushed away. The flushing tank, besides being automatic, can also be discharged at will by the sweeper when only partly full.

This arrangement proved to be useful and sanitary and free from smell, and did away with the hand removal of fœces; but it proved wasteful in regard to the amount of water used.

Plate 35 shows the above system in detail.

The universal term "nahani" is used to describe a small sink in an Indian house, with or without a water connection, either inside or outside a room, built primarily for washing purposes, but often used indiscriminately for urinating and defœcating, particularly by children. It is usually about 3 feet square, constructed in a corner and raised some 4 inches above the surface of the floor, with a concrete or brick-work surface plastered with lime or cement, and surrounded on the open sides by a small kerb or a dwarf wall. All "nahanis" are connected to the waste water pipe fixed to the outside of the house by means of a "nahani" trap, previously des-

cribed or a Tee-shaped pipe. If the latter is used, the discharge into the waste water pipe is through a cistern head, but, in the case of a "nahani" trap, it is connected direct with the waste water pipe, which is carried up above the building as hereinafter described.

Ventilating Pipes.--No house drainage would be complete without a regular system of ventilation. The theory of ventilation is that (*a*) the air of the drain being at a higher temperature than the external air and therefore lighter, a current is formed through the outlet shaft; (*b*) that the warm air carrying a certain amount of water vapour which being lighter than dry air causes it to rise; (*c*) that wind blowing across the open end of the outlet shaft creates a slight vacuum. On the sewer side of the intercepting trap, a 3-inch cast-iron pipe should be fixed to the drain and carried up the side of the house to a

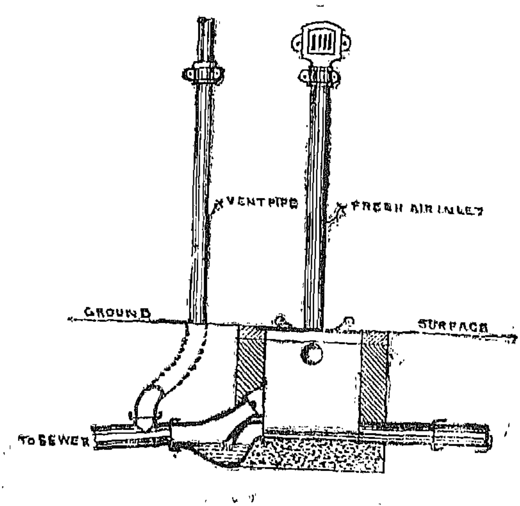


FIG 27

height of 5 feet above the eave of any roof, that may be within 20 feet thereof. The inspection chamber at

the lower end of the pipe drain should be connected with a fresh air inlet pipe fitted with a mica valve as shown in Fig. 27. This fresh air inlet pipe should be placed against a wall or a post, whichever is most convenient, and should be about 6 feet above ground level. The head of every pipe drain should be ventilated with a 3-inch cast-iron ventilating pipe, similar to the one hereinbefore described. In the event of a pipe drain being more than 100 feet in length, a ventilating pipe should be fixed midway and connected with the intermediate inspection chamber. All soil pipes should be carried up to 5 feet above the eaves of the roof. In case of a tier of water closets one above the other, a 2-inch anti-siphon pipe should be taken from each water closet, except from the one on the highest floor, and carried up above the roof the same height as the soil pipe. In the event of waste water pipes being fitted with "nahani" traps, each of these pipes should be carried up as a ventilating pipe, 5 feet above the eaves of the roof of the house. All such pipes carried up above the roof should be protected at the top with a wire dome.

Gullies.—As already stated, "gullies" are the narrow passages left between houses for drainage purposes and also to give access to the privies and to admit light and air. Such gullies should always be paved with a nonporous stone set in concrete and jointed with cement, or should be constructed of concrete, finished off with a coating of cement plastering, (1 to 1), one inch in thickness. The surface of the gully should slope towards the centre as shown in Fig. 28, and also longitudinally towards the street.

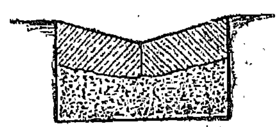


FIG 28

At the lower end of the gully and in the centre of it a jump-weir should be constructed, as shown in Fig. 29, so that while any ordinary flow of sewage will discharge

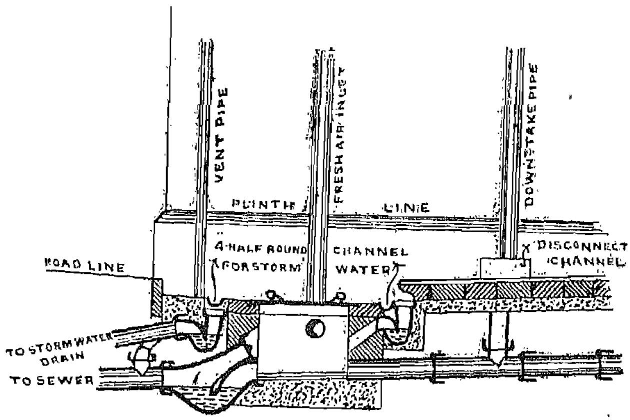


FIG 29

over the jump-weir into a trap connected with the sewer, a rush of storm-water will pass over the opening and discharge into another trap connected with the storm-water drain. In the event of its being considered necessary to flush the gully, a flushing tank as shown in Plate 36 will be found suitable. This tank is fitted with an annular siphon and a reverse ball valve and should have a capacity of from 20 to 50 gallons.

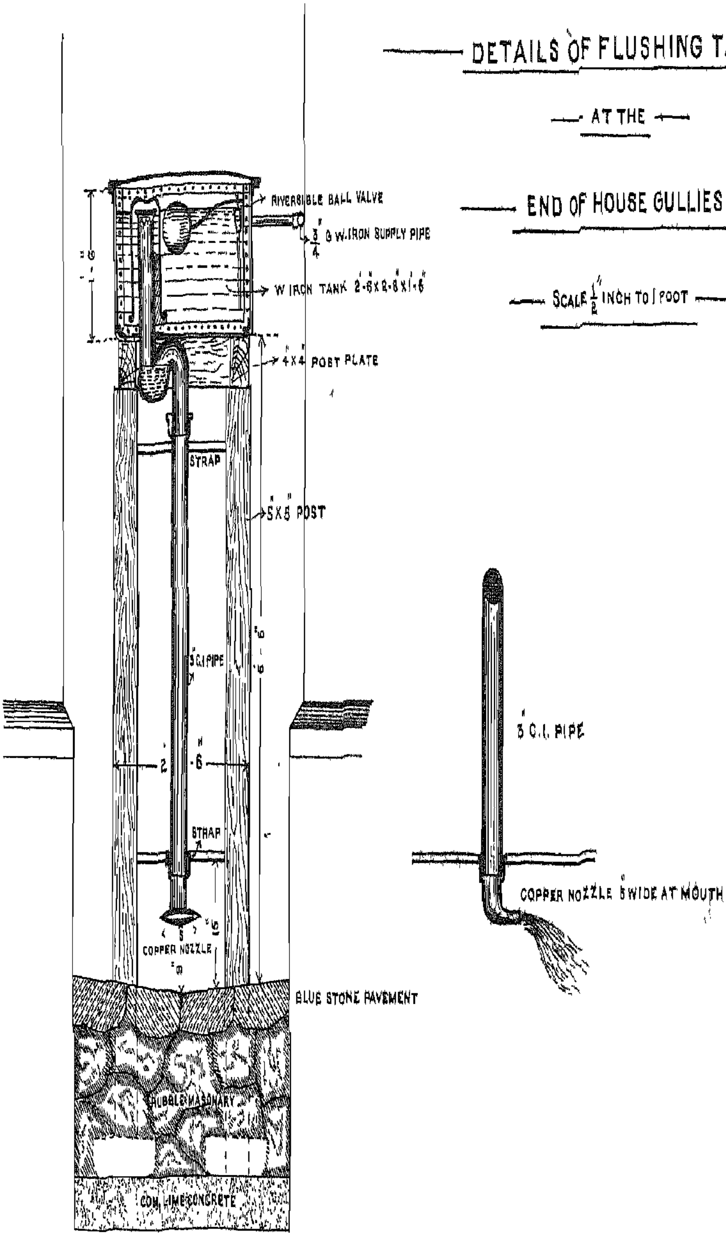
All down take pipes, ventilating pipes, and soil pipes should be tested for efficiency and soundness by means of the smoke test as follows :—A smoke rocket should be inserted in the bottom of the cast-iron pipe, if it is not connected directly with the drain; or, if otherwise, into the inlet in the nearest inspection chamber, and fixed there so that all the smoke will pass up the pipe. As soon as the smoke commences to issue from the top of the ventilating pipe, the pipe should be closed at its top end to

DETAILS OF FLUSHING TANK

AT THE

END OF HOUSE GULLIES

SCALE ½ INCH TO 1 FOOT



enable the smoke under pressure to find its way out of any leaky joints or cracks or perforations in the pipe.

For house connection purposes, houses in the City of Bombay are divided into the following three classes, each class being further sub-divided into (*a*) & (*b*).

(1.) Detached houses in compounds.

(2.) Attached houses without gullies.

(3.) Houses of all other classes.

(*a.*) Houses where it is desirable to drain the premises by a pipe drain.

(*b.*) Houses which are not within 100 feet of a Municipal sewer.

Class I.

With houses of this class open drains as branch drains should be made use of as far as possible, but where water closets are constructed, then the branch drains connected with the closets must be closed.

Class II.

In houses of this class an open drain is not possible, and therefore the closed pipe drain must be laid under the building.

The conditions laid down in Bombay in regard to the construction of drains which have to be laid to pass beneath any part of a dwelling house are :—

"Every owner shall so construct a drain only when any other mode of construction is impracticable, and not even then without the written permission of the Municipal Commissioner. It should be so laid that there shall be,

between the top of the pipe and the surface of the ground under such building, a depth at least equal to twice the internal diameter of the pipe drain.

"The drain shall be laid in a straight line for the whole of the distance beneath the building and be completely embedded in and covered with good concrete, nowhere less thick than 6 inches outside the drain, measured in any direction.

"At each end of such portion of the drain, beneath the building, a 6-inch trap shall be inserted outside the building, giving a drop of at least 2 inches into the contained water with a 4-inch inspection inlet brought up to within 9 inches of the surface, and covered with a cast-iron grating 9 inches by 9 inches set in a frame of stone or timber standing up 2 inches above the general surface so as to exclude storm-water. On the lower side of the siphon, a 4-inch stoneware branch pipe shall be connected with the drain, and brought up above the ground and continued with a cast-iron pipe above the roof of the building for ventilation purposes, in addition to such means of ventilation as are ordinarily directed to be provided."

Class III.

In all such houses the premises should be drained by means of an open drain. The only exception to this is in the case, where one or more sides of a house abut on a public road, under which circumstances there is no alternative but to provide a closed pipe drain. In houses of this class also where water closets are constructed, closed pipe drains must always be laid.

Sub-division (A).

In regard to this class of houses sanction is accorded to owners desirous of having closed drains, instead of open, but in such cases the following conditions are laid down :—

"The pipe drain shall be laid at a gradient of not less than 1 in 50. The connection between the street connection pipe and the branch drain with the inspection chamber, the intercepting sewer trap and the fresh air inlet pipe, shall be made at the house-owner's expense. Inspection chambers shall be placed at every 100 feet, or less if there is any change of direction, and built in accordance with the conditions prescribed in the earlier part of this Chapter. The branch drain must be ventilated by a 3-inch cast-iron ventilating pipe, and every ventilating pipe, soil pipe, and anti-siphon pipe must be protected at the top by a wire dome and carried up in accordance with conditions before laid down. Nahani traps should be provided for every nahani except those on the ground floor. All waste water pipes must be of cast-iron 3 inches in diameter, and all soil pipes 4 inches in diameter. All soil pans for water closets must be of porcelain or glazed stoneware, provided with a flushing rim and a trap of similar material. Every water closet must be provided with a 3-gallon tank for flushing purposes and in cases of tiers of water closets, the anti-siphonage pipes must be fixed as hereinbefore described."

Sub-division (B).

In regard to this class of buildings, there is at present no law, by which the Corporation of Bombay can compel the house-owner to connect his premises with a Municipal sewer in the public roads. In such cases it often happens that there is no sewer except at a very considerable

distance from the house, and therefore, unless it is practicable to sanitarily dispose of the sullage in a garden for the irrigation of plants, it must be drained on the hand removal system into a cesspool. In a case where a cesspool is constructed, its capacity below the invert of the drain discharging into it should be sufficient to hold a twenty-four hours' flow. Such a cesspool should be placed as far as possible from any dwelling and should be ventilated by a cast-iron or galvanized iron pipe, not less than 3 inches in diameter, and of such a height as to ensure its causing no nuisance.

It is desirable to have a cesspool for privies separate from that for nahanis, and the size of this cesspool should be calculated to have a capacity of 3 cubic feet per privy seat with a minimum of 10 cubic feet.

Cesspools should always be emptied once every twenty-four hours, and preferably at night.

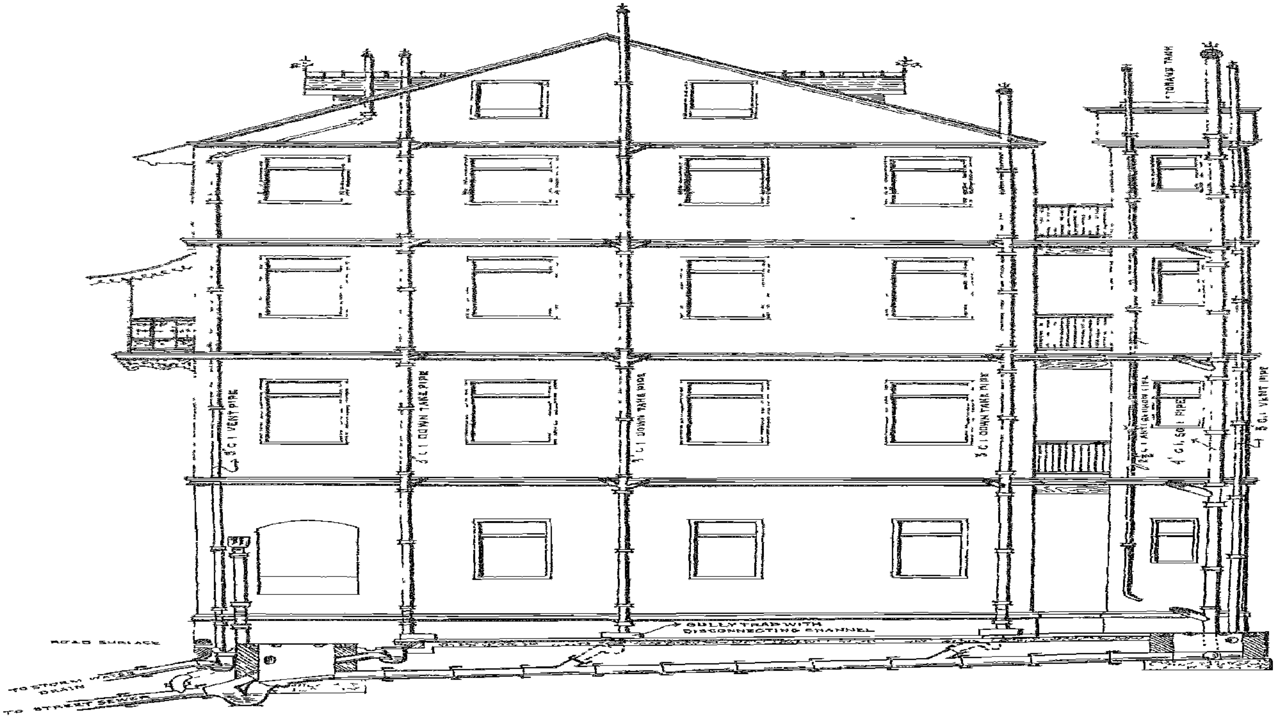
Such a cesspool should be constructed of brick-work laid on concrete internally rendered with a ½-inch layer of cement and sand (1 to 1). The walls of the cesspools should be brought up 6 inches above the surface of the ground, so that surface water may not be able to flow into it, and covered with an air-tight cover to prevent noxious odours escaping.

No cesspools should be constructed within 20 feet of any well used for drinking purposes, for although the cesspool may be constructed so as to be perfectly water-tight, it is always liable to overflow.

It is desirable also in houses of this class to make use of open drains rather than closed drains. Many instances are within the knowledge of the Author, where the sewage of such buildings has been successfully dealt with by

PLATE 37

TYPE OF HOUSE-CONNECTIONS WITH A 6" PIPE DRAIN



distance from the house, and therefore, unless it is practicable to sanitarily dispose of the sullage in a garden for the irrigation of plants, it must be drained on the hand removal system into a cesspool. In a case where a cesspool is constructed, its capacity below the invert of the drain discharging into it should be sufficient to hold a twenty-four hours' flow. Such a cesspool should be placed as far as possible from any dwelling and should be ventilated by a cast-iron or galvanized iron pipe, not less than 3 inches in diameter, and of such a height as to ensure its causing no nuisance.

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SCALE 8 FEET TO AN INCH

small Septic Tanks and Filters, or by a series of filters, the effluent being run into masonry tanks and used for gardening purposes. Such arrangements, if constructed scientifically, are quite satisfactory.

Plate 37 shows a house fitted with water closets and drained, according to the arrangements already advocated, by means of a 6-inch pipe drain. It will be seen that the drain is laid at a gradient of 1 in 50, and that at its higher end there is an inspection chamber covered with an air-tight cast-iron frame and cover. Connected to this inspection chamber are a 4-inch cast-iron soil pipe from the water closets and a 3-inch cast-iron pipe ventilating the pipe drain. At the lower end of the pipe drain is another inspection chamber, into the brick-work of which is built an intercepting sewer trap with a cleaning eye; the cap of this cleaning eye should always be securely fixed, as otherwise gas from the sewer will have a free discharge into the chamber. Connected with this chamber there is also a 3-inch fresh air inlet pipe fitted with a mica flap valve, which supplies fresh air to the whole length of the pipe drain between the inspection chambers. Under each waste water pipe is fixed a 6-inch by 6-inch trap, which is connected to the pipe drain by means of a 4-inch branch pipe.

All the waste water pipes are 3 inches in diameter, coated with Dr. Angus Smith's solution, and carried up 5 feet above the eaves of the roof, the ends being protected with wire-domes. The nahanis on each of the floors are connected with the waste water pipes by means of nahani traps. The soil pipe from the water closets is 4 inches in diameter, and is also carried up 5 feet above the eaves of the roof of the house. Each soil pan is trapped and con-

nected with the soil pipe by means of 3-inch branches. Alongside the soil pipe is a 2-inch anti-siphon pipe connected to the traps of the soil pans on the ground and first floors. A storage tank is fixed above the water closets to provide a constant supply of water to the 3-gallon tanks for flushing the water closets.

Connected with the pipe drain and between the intercepting trap and the sewer is a 3-inch ventilating pipe, which is carried up the side of the house to 5 feet above the eaves of the roof, thus preventing the seal in the trap being forced by any pressure of gas in the sewer. The fresh air which enters by means of the mica flap valve connected with the inspection chamber at the lower end of the pipe drain is discharged at the higher end of the drain through the ventilating pipe connected to the inspection chamber at that end. All soil pipes and waste water pipes are trapped at their connections with the buildings and carried up above the roofs as ventilating pipes. Each waste water pipe is disconnected from the pipe drain at the bottom, and discharges its sullage through a short length of channel into a trap. The water closets are entirely separated from the main buildings by a passage 3-feet wide.

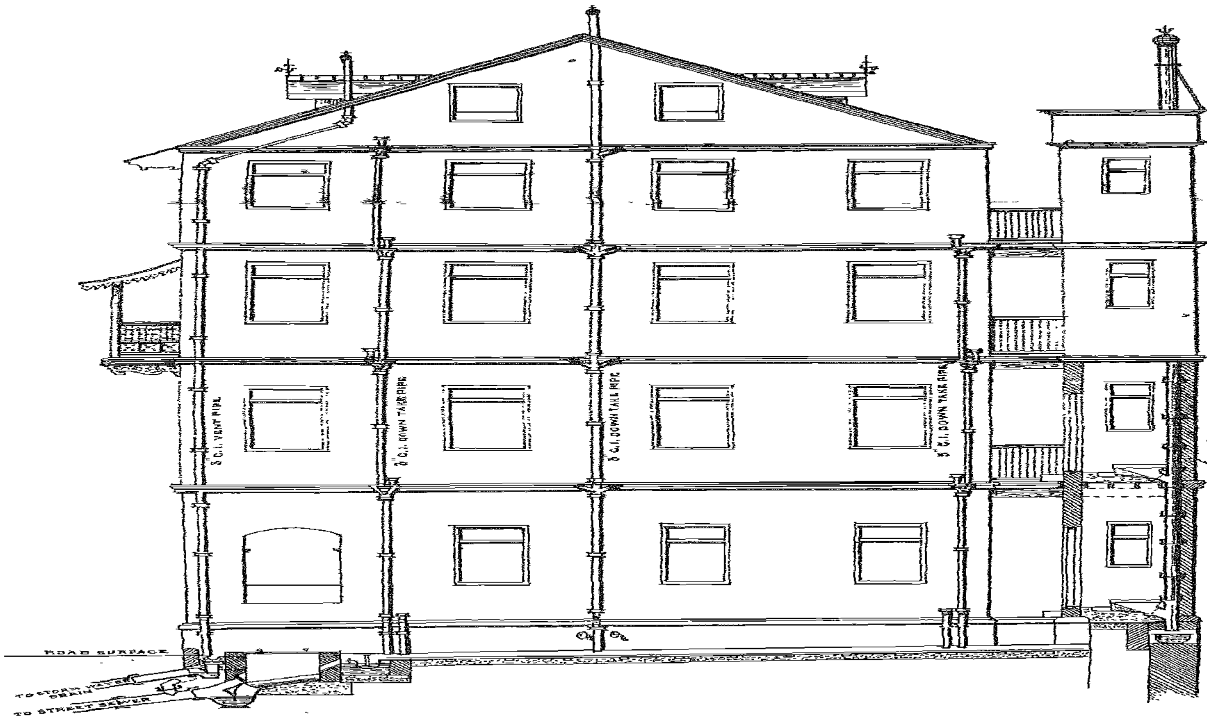
It will thus be seen that the whole of the building is guarded against gas entering it from the sewer or pipe drain.

The storm-water falling in the gully is discharged over a jump-weir into a trap connected with a storm-water drain in the street.

Plate 38 shows the same class of building with Native privies and drained by means of an open drain. The open drain is constructed, as described earlier in this Chapter, at a gradient of 1 in 100, and at its lower end it discharges

PLATE 38

TYPE OF HOUSE-CONNECTIONS WITH AN OPEN DRAIN



into a small catch-pit fitted with a grating. This catch-pit is to arrest heavy matter in the sewage, and the grating is to intercept floating substances such as leaves, etc. The sullage after passing through the catch-pit discharges into an inspection chamber into the wall of which is built the intercepting sewer trap, as explained in the description of the previous house.

The privy sullage discharges on to the higher end of the open drain through the open sides of the basket placed under the shaft of the privy. The waste water pipes discharge directly on to the open drain without any traps. In two instances in this house the discharge from nahanis is directly on to cistern heads, but in one instance the nahanis discharge through nahani traps, as explained in the description of the previous house, and in this case the waste water pipe is carried up above the eaves of the roof and finished with a wire-dome.

The privies are separated from the main building by a passage 3 feet wide, and discharge their contents into a 6-inch stoneware pipe acting as a privy shaft. The ventilation of the sewer is provided for by a 4-inch stoneware pipe connected with the 6-inch pipe drain on the sewer side of the intercepting sewer trap, and continued by a 3-inch cast-iron pipe carried up above the eaves of the roof of the house and finished with a wire-dome. The storm-water from the gully is discharged by means of a jump-weir into a trap fixed at the lower end, and connected with the storm-water drain in the street.

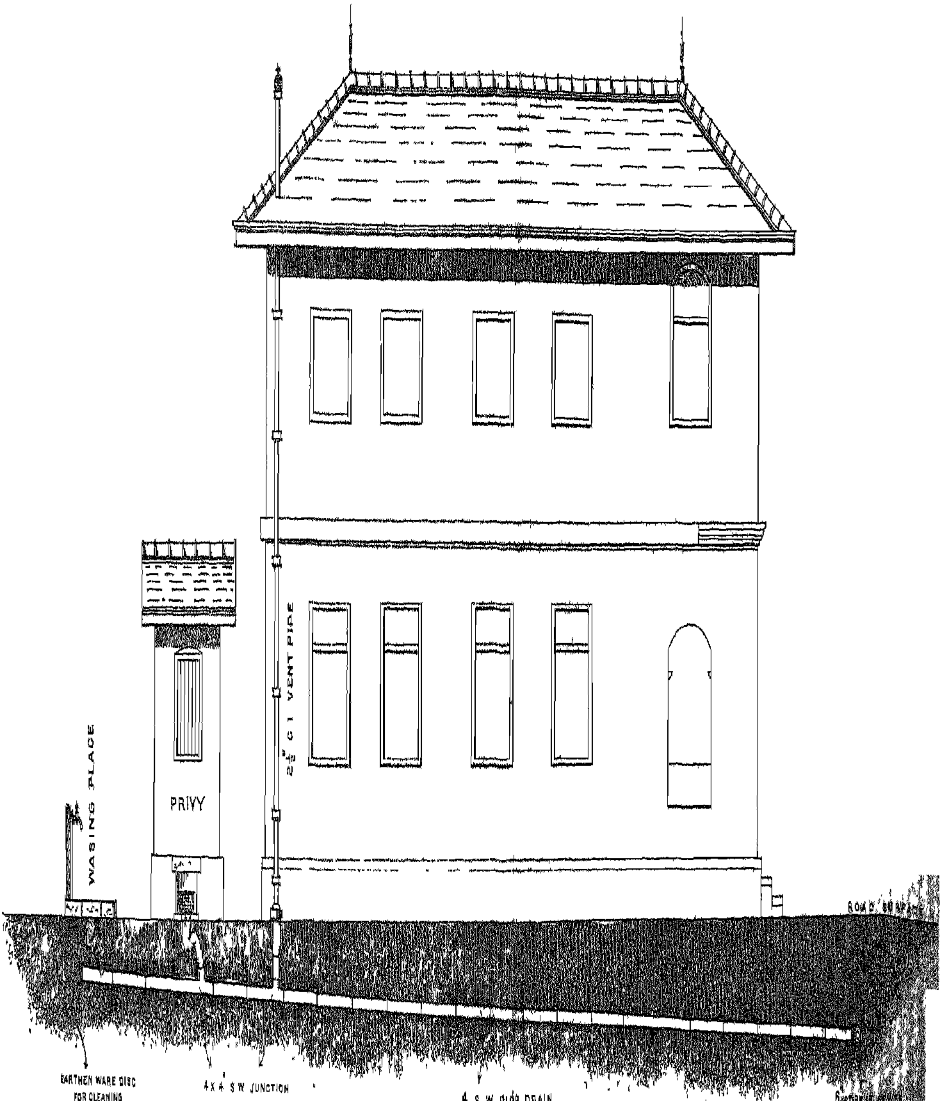
It may be argued, perhaps rightly, that the house connections described in this Chapter are in many ways too complicated and expensive, except for large cities with high buildings, and that in a mofussil town something much

simpler would suffice. Some years ago the Author visited Secunderabad to advise on the drainage of the town including the house connections. After inspecting many of the houses the arrangement, as shown in Plate 39, was recommended. This consisted in connecting the washing place or nahani at the back of the house by means of a 4-inch by 4-inch stoneware trap, and a 4-inch stoneware pipe to the pipe sewer in the street. On the same line of the 4-inch pipe, but lower down than the nahani, is connected the privy of the premises, fœces being caught in a basket and the sullage draining through a 4-inch by 4-inch stoneware trap to the 4-inch drain.

At first it would appear that the absence of any sewer trap near the junction of the house drain with the sewer would be likely to allow sewer gas to pass up the house drain and, in the event of the water in the traps having evaporated, escaping within the precincts of the houses. On the other hand, however, it must be remembered that practically no night soil passed into the sewers, and that the sewage was of a weak, and more or less inoffensive nature. It was, therefore, very improbable that any serious accumulation of sewer gas would take place, and even if this remote contingency did arise and a nuisance was noticed, such nuisance would be easily remedied by pouring a little water into the traps. Further, no connections of any kind were made with the interior of the houses, and taking all these facts into consideration, the Author was satisfied that such a comparatively expensive accessory as a sewer trap could in this instance be dispensed with.

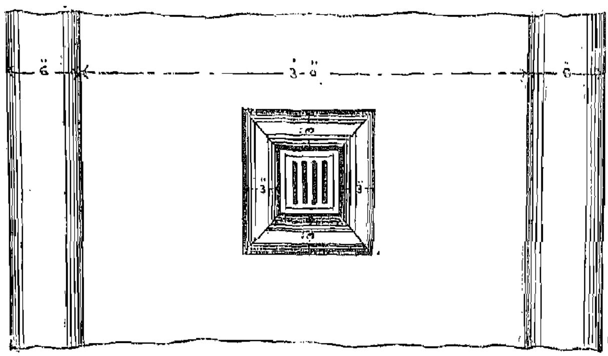
The end of the 4-inch drain should be ventilated by means of a 3-inch pipe, carried up above the roof or fixed on a post 10 feet above the ground. But if for economy it is desired not to erect a ventilating pipe in all cases, it may only be done at the higher parts of the district.

A SIMPLE TYPE OF HOUSE CONNECTIONS



SCALE 6 FEET TO AN INCH

PLAN.



CROSS SECTION.

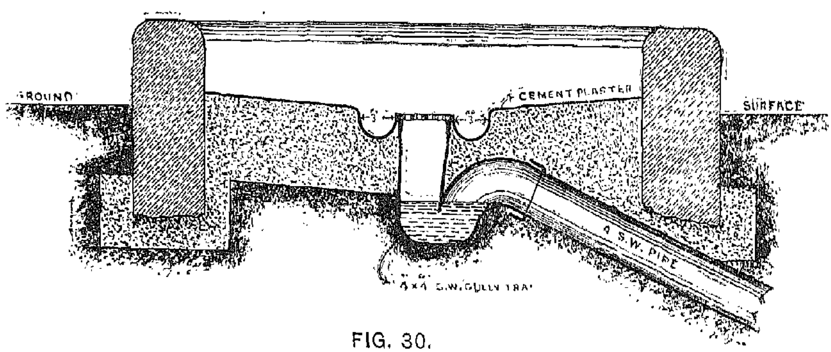


FIG. 30.

Fig. 30 shows a detail drawing of a washing place which may be constructed of any size to suit the premises for which it is intended. It should be built of concrete rendered with cement plaster, the walls surrounding it being of brick-work; three sides may be raised, if desired, to a height convenient for privacy.

The slope of the washing place should be towards the trap, which should be covered with a grating.

This arrangement is economical, and eminently suitable for the one-storeyed buildings with small compounds, which are mostly met with in the mofussil towns and might be applied in many of the old houses in villages.

In the out-lying villages of Bombay, where drainage is necessary, public detached washing places and latrines for the use of small and poorly-built houses should be erected, instead of each individual house being given its own convenience connected with the pipe sewer.

Drainage of Horse Stables.—Much experience and knowledge has been obtained in Bombay as to the best method of draining stables, for there are many very large stables for the reception and sale of the immense numbers of Arab and Australian horses which are annually imported. For horse stables, both public and private, the floor of each stall should consist of a layer of 6 inches of lime concrete, laid at a slope equal to 3 inches in 9 feet, or 1 in 36. Above the concrete should be put down a 3-inch layer of good muram, well-rammed and finished off to the same slope as the concrete. Meeting the muram and at right angles to the stall, should be constructed a V-shaped channel, 12 inches wide, formed of stone or other suitable material. This channel should have a gradient of not less than 1 in 100 discharging into a six-inch stoneware trap connected to the branch drain of

the premises. As the muram works up under the feet of the horses, it requires to be renewed, and this should be done whenever and wherever necessary.

Experience has shown that the above arrangement for horse stables is better in this country than any paving, many kinds of which have been tried and have been found failures. After some use the muram becomes consolidated and firm, but it is always softer than stone or brick for the feet of the horses.

Buffalo Milch Cattle Stables.—In this class of stables muram is of no use, and the floor of every such stable should be paved over the whole area with stone paving laid on a 6-inch bed of concrete. This is rendered necessary because of the frequent washing which buffaloes daily receive. The paving should slope at an inclination of 1 in 60 towards an open stone channel. The channel, as in the case of horse stables, should be V-shaped with a gradient of 1 in 60 towards a trap on the branch pipe drain. In connection with a stable of this class, and on account of the large quantity of solid matter passed away in the sewage, a catch-pit should be constructed as in

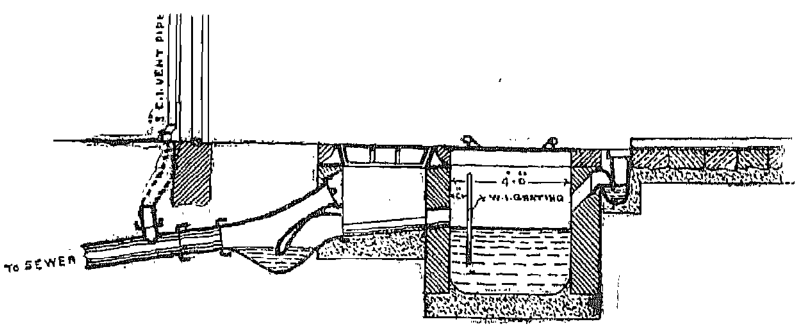


FIG. 31

Fig. 31. During the dry season much of the buffalo excreta is removed by hand and mixed with hay or straw,

and the siftings of cotton seed, and made into cakes for fuel purposes. These cakes, when dried in the sun, are ready for use, and in many parts of India are almost the only fuel available. The catch-pit should be placed at a point where the stable drain ends, and the branch pipe drain commences. It should be 3 feet by 4 feet by 5 feet deep, and be provided with a wrought-iron grating, the bars of which should be fixed ½ an inch apart to prevent the stable litter passing through into the branch drains.

Bullock Stables.—As a general rule, no special drainage is required for bullock stables, a foundation of good well-rammed muram being all that is necessary. The reason of this is that the droppings of bullocks are much in request, and are largely used for the plastering of the floors of living rooms which have earthen floors. Mixed with fine red earth, bullock excreta makes a plaster, which has a considerable binding property and, because of the ammonia in it, is a safeguard against fleas and other vermin.

CHAPTER V.

Sewage Disposal.—The best method of sewage disposal is always a most difficult question to decide; as a false move may often have far reaching and very serious consequences. The question therefore should invariably be given the most deliberate and painstaking consideration. The difficulties which are met with in many inland English towns do not as yet exist in India. Land in England is often only available at a prohibitive price, and legislative restrictions are rightly placed on the discharge of sewage into rivers.

The different systems of disposal, any of which may be adopted according to local circumstances, may be classified as follows :—

(1) Dry earth ;
(2) River and sea outfall ;
(3) Land irrigation ; filtration ;
(4) Precipitation and electrolysis ;
(5) Biological treatment.

Dry Earth.—In India, and in fact in most Eastern countries, the dry earth system is the earliest mode of the disposal of sewage and is even now the most usual. In sparsely populated districts, this system, if efficiently carried out, still finds approval. The fœcal matter is collected, removed and buried outside the town. The sullage water, if not removed by carts, finds its way through open channels to pits, where it is allowed to soak into the ground. The usual procedure is to remove the fœcal matter to trenches and cover it with earth, and the mis-

take is often made of excavating these trenches too deep to allow of the bacteria dealing efficiently with the fœces. Trenches should be three feet wide by nine inches deep and one foot apart, and covered with soil slightly raised above the surrounding level.

With increased education and the march of science in sanitation, this system of disposal is doomed, and calls for no further comment.

River Outfall.—The sewage of towns situated on the banks of rivers is usually discharged into these rivers, but this should never be done without some preparatory treatment. The degree of purification required depends upon the relative volume of the sewage to the minimum flow of the river and in cases where the volume of the river is large compared with the amount of sewage, it is not generally necessary to construct works which are expensive or of great magnitude, as the river may be safely relied on to complete the final purification of the effluent. Unfortunately, however, many towns in India situated on large rivers take no care to in any way purify the sewage before it is discharged. Many of the rivers are considered Sacred and those, that are perennial, serve the double purpose of being utilised for bathing and providing potable water all through the year for many of the inhabitants on their banks. There is no doubt that pollution from unpurified sewage is a frequent cause of epidemic cholera. Rivers in India, even those which are large, are apt to run so perilously low in the hot season that it is imperative that sewage should not be discharged into them without having previously been submitted to some form of purification. Suitable land is nearly always available, so no great difficulty should be experienced.

Sea Outfall.—In discharging a large bulk of sewage into the sea in the proximity of a town, great care is necessary to select a position, where the sewage will not be thrown back on to the foreshore, as this is liable to cause a most offensive, and, as time wears on, an increasingly dangerous nuisance. A most careful study of the tides should be made and for this purpose float observations at all states of the tide and prevailing wind and weather should be most carefully taken and considered together. The greatest difficulty occurs during neap tides, when the range of tide is not great and sewage is likely to remain for some hours in the neighbourhood of the outfall. A sea outfall should always be taken out as far as possible from the shore, but never to a less distance than will cause it to be covered with water even at the lowest spring tide. The liquid of the sewage rapidly becomes diffused in the body of the sea water, but the solid matter may persist for some considerable period especially as sea water delays the oxidation of the solid organic matter and it is not until some hours after discharge that purification sets in and it is broken up and dissolved. Owing to its specific gravity being less than that of sea water, sewage floats on the surface, open to the influence of both tide and wind; and, if carried down to a foreshore, is liable to cause dangerous deposits. The experience at the outfall in Bombay shews that the sewage discharged on an ebb tide is carried for a considerable distance along the coast towards the residential part of the Island, and is not all broken up by the sea for at least four hours after its discharge from the outfall. In a subsequent chapter this matter will be further referred to and certain float observations explained.

Consideration should be given in a sea outfall to the question of the local fisheries. Fresh sewage discharged into the sea does little harm, in fact in Bombay it is popularly believed to have very largely increased the number of fish on the part of the coast concerned. Putrefying sewage is, however, dangerous, and will destroy or drive away fish. Sea birds are great scavengers and greedily eat all floating matter around an outfall that they can get hold of, but they also avoid putrid sewage. Sewage in India may be considered to be fresh until it is 6 hours old.

Land Irrigation and Filtration.—Where neither river nor sea disposal is available, sewage is sometimes deposited on a reserved area of land, in which case the soil is relied on for filtering and oxidising it. Any land is, to a greater or less extent, useful for sewage irrigation, but a sandy calcareous or porous loamy soil is the best. Clay land is not well adapted for this purpose. Suitable land should be laid out in level beds, and the sewage applied in turn to each bed. If a porous stratum of sand or gravel underlies the beds, the liquid will naturally drain away with the subsoil water, but in certain cases it will be found necessary to insert underdrains to carry off the liquid. The drains should be laid at a minimum depth of three feet, and in such a manner as to prevent direct vertical percolation into them. Land used for sewage filtration purposes should be constantly ploughed or turned over to allow of aeration, suitably cultivated, and kept free from weeds, or anything that will choke the surface of the ground. Porous soil under advantageous circumstances will dispose of 30,000 gallons of sewage per acre per day. The

worst soil is probably heavy clay soil which will not safely dispose of more than 5,000 gallons per acre per day. If possible, sewage should not be discharged on to land without previous treatment in order to remove the solids, as they will rapidly coat the land with a layer of decomposing organic matter. This will hinder the action of the aerobic bacteria in the soil, and quickly create a nuisance.

Where previous treatment cannot be resorted to, intermittent application of small quantities of the sewage should be followed in order that the liquid may drain away and the solids be broken up, thus permitting air and oxygen to refill the interstices of the soil. The process is naturally slow, for until air has reached all the interstices of the soil, the purifying action cannot recommence.

The amount of oxygen available varies with different soils and is at the best limited, and further the underground circulation of air is very slight and without oxygen the aerobic bacteria cannot thrive.

Precipitation.—Under this head is included any system which depends on chemical treatment of the sewage, preparatory to its being discharged to the sea, river or land in order to precipitate the solids and deodorise or disinfect the liquid. Such treatment is rarely necessary in India where land is generally available for irrigation purposes, and where the sewage is for the most part what is known as domestic rather than trade sewage. A good precipitant must be cheap and should cause a rapid subsidence of all organic matter in suspension. It should not be actively or cumulatively poisonous,

otherwise it would be dangerous to human and animal life. It should have no distinctive colour as this would arouse sentimental objections, and if a chemically treated effluent is to pass into a stream or be used for the irrigation of crops, the resultant effluent should be neutral or slightly alkaline.

A large variety of processes have been tried in Europe but all are expensive, and create a large amount of sludge, and for reasons given above, it is not proposed to go into them in detail.

Electrolysed Sea water.—Some years ago shortly after the outbreak of the first Plague epidemic, when every promising disinfecting system was eagerly considered, an experiment was tried in Bombay of electrolysing sea water and mixing it with the sewage in the sewers so as to destroy organic matter. The system was invented by a Monsieur Hermite, a Frenchman, and has been tried in several places on the Continent and at one or two places in England with a certain measure of success. In this system sea water, or, in default thereof, an aqueous solution of chloride of magnesium and chloride of sodium, is subjected to what is known as "Electrolysis." Under the influence of an electric current the water and the salt are decomposed and as a result of this decomposition, at the positive pole of the battery, an oxygenated compound of chlorine, very unstable and possessing a considerable oxidising and consequently disinfecting power, is obtained, and at the negative pole is formed an oxide which has the power of precipitating certain organic substances. The sea water, or its equivalent aqueous solution, when subjected to the action of the electric current as described above, is called electrolysed

sea water, and is a good disinfecting liquid. It is practically inodourous but is a powerful antiseptic. It destroys microbes, renders sulphuretted hydrogen innocuous and effects a complete sterilization, and deodorization of all liquid matter. The installation necessary for this system of disinfection comprises (*a*) a central station containing a dynamo and an electrolysing apparatus, a pump to raise the sea water, and tanks for the storage of the same, unless it can be obtained at all states of the tide, and also tanks for the storage of electrolysed sea water; (*b*) the provision of a separate system of mains, service pipes and domestic fittings for distribution of the fluid in the same way as in the case of ordinary water or gas supply with branches near the edge of the road to flush the sewers and storm-water drains or to water the streets with the disinfecting fluid.

The electrolysers are of three sizes. Size A consists of 200 platinum electrodes and 54 zinc disks, B consists of 104 platinum electrodes and 28 zinc disks, and C consists of 44 platinum electrodes and 12 zinc disks. Electrolysers of the first size are useful for industrial requirements. Those of the second are smaller and better adapted to installations on a small scale, such as those for hospitals, and those of the size C are only suitable for still smaller institutions. Several electrolysers can be simultaneously used by connecting them in a series. It is said that the maximum grouping that can be effected advantageously is 10 electrolysers worked by a single dynamo.

The current sent into an electrolyser of type A is generally from 1,000 to 1,200 amperes, of type B from 500 to 600 amperes, and of type C from 250 to 300 am-

peres. The electro motive force (E. M. F)., required in all cases, is from 5 to 6 volts for each electrolyser. The dynamo required to give off these currents is similar to that used for electro-plating and other similar purposes, and its distinguishing feature is its capability of producing a large amount of current at a low potential.

The installation fixed in Bombay consisted of two electrolysers capable of producing 1,000 grammes of chlorine per hour, or 440 gallons of electrolysed sea water containing 0.5 grammes of chlorine per litre. (Gramme is a French weight and is equal to 15·432 grains Avoirdupois. Litre is a French measure and is equal to 1·7607 British pints.) Assuming the dynamo worked for 12 hours a day, the amount of electrolysed sea water produced should be 5,280 gallons. When first started, the installation was worked in connection with a night-soil depôt, which disposed of 74 tons of night-soil per day. It was found that 0·5 of a gramme of chlorine was required to disinfect or deodorise one litre of sewage in 10 minutes, and therefore 16,576 gallons of electrolysed sea water were required to sterilize the whole of the night-soil of the depôt. Much good was done by the use of this electrolysed sea water in lessening the smell of the night-soil depôt and no doubt in sterilizing the fœcal matter. An experiment was tried by discharging the fluid straight into the sewer, but the quantity of the fluid produced was not large enough to make any appreciable difference in the large bulk of sewage, which flowed at the rate of 3,500 gallons per minute. The experiment was continued for 34 days, during which time 22,000 grammes of chlorine were produced per day, equal to 748,000 grammes or 15 cwts. of total production, at a cost of Rs. 1,039-6-1

or Rs. 1,386 per ton. Unfortunately for financial success, however, good commercial chloride of lime, containing 30 to 35 per cent. of free chlorine, may be purchased in Bombay for Rs. 260 per ton, which would bring the actual cost of chlorine to Rs. 780 per ton, which is little more than half the cost of producing the same amount of chlorine by electrolysing sea water, even without taking into consideration the interest on capital expenditure necessary in the latter case.

The plant was tried for a further period, but with very little difference as regards cost. The fluid was also used in Bombay for flushing gullies and disinfecting privies, but the cost of cartage made the process more expensive than ordinary disinfectants. On account of expense, therefore, this system is only recommended for such places, if any exist, where the price of other good disinfectants is so exorbitant as to justify it.

Biological Treatment.—Of late years the knowledge of the biological treatment of sewage in Europe has rapidly advanced. The Royal Commission on Sewage Disposal has brought together the experiences of all the greatest Sanitarians in England and it will almost appear that the present state of our knowledge has now so far advanced as to leave little to be learnt in the treatment of ordinary (as opposed to trade) sewage. It is not proposed to refer at any great length or detail to this important subject, because there are many standard works written which deal entirely with the question of Biological Treatment. The Interim Report of the Royal Commission (Volume 11, Evidence) is strongly recommended to students and others interested in the subject.

Before sewage can be thoroughly purified by a biological process it must undergo two changes. The solid organic matters must be liquefied, the complex nitrogenous and other organic compounds in the liquid of the sewage split up into their simpler forms and the whole must then be oxidised. To obtain these changes sewage must be dealt with first by anaerobic and secondly by aerobic bacteria, (terms invented and first used by Pasteur). All sewage contains within itself the necessary bacteria for its own purification, and it has been proved that these organisms will quickly grow and multiply in water-carried sewage and rapidly liquefy the solid matters and finally set up the oxidation of the organic matter, changing it into harmless forms. Mr. Scott Moncrieff, a Civil Engineer, claims to be the first to have recognised that organic matter in sewage could be dealt with by micro-organisms contained in the sewage itself. These organisms are classified into anaerobic and aerobic, *i.e.*, those whose work is performed in the absence of free oxygen and those whose very existence depends upon the free access and presence of free oxygen.

The anaerobic treatment of the sewage, which produces the liquefaction of the solids, preferably takes place in a tank constructed in such a manner, that the velocity of the sewage on entering it is so reduced that the solids are deposited and that the organisms can thrive in it and liquefy the organic matter during its progress through the tank. For this to be efficiently performed a tank should be large enough to hold a 24 hours' supply of crude sewage. Such a tank is called a "Septic Tank," a name given to it by Mr. Donald Cameron, M. INST. C.E., the late City Engineer of Exeter. Septic Tanks may be

either covered or open, but it has been now proved without doubt that the liquefying effect is the same in an open as in a closed Septic Tank, and the reason of this is probably that scum quickly collects on the surface of the open tank, finally excluding light and air and forming a natural cover on it.

When sewage has undergone anaerobic treatment for the specified time of 24 hours, it is almost wholly without oxygen, that gas having been converted into carbonic acid gas by the decomposing organic matter produced by the mixed organisms which arrive in the tank in the sewage.

The next and second process of purification is performed by the action of the aerobic bacteria which are the organisms which live only in the presence of atmospheric oxygen. These bacteria will work under two conditions, *viz.*, in suitable land which should contain lime or some other base or in an artificial filter constructed of some material which will hold air in its interstices. It must be remembered that in all artificial filters we only imitate the process which nature performs for us in land, but in the case of land, however, it is only the first few inches which are usefully employed by the aerobic bacteria, whereas in an artificially constructed filter the whole of the depth can be employed if the filter is properly constructed. The chemical change made in the septic effluent by the filter is the conversion of the various nitrogenous substances such as free ammonia into the harmless compounds of nitrites and nitrates.

The less free ammonia and the more nitrates found in the effluent the greater the degree of purification. This second change is made with extraordinary quickness, often within 10 or 15 minutes.

Much attention has been given to the question as to whether biological treatment destroys pathogenic germs that may exist in the sewage, but it appears that there is at present no acknowledged method which enables a bacteriologist to say with certainty that a sewage effluent is without pathogenic germs. However, as it is unlikely that a sewage effluent in its condition as an effluent would be used as potable water, this question can be considered as an entirely separate one to that of the purification of the sewage. The question has provoked much argument among bacteriologists who differ as to whether any or all pathogenic germs are destroyed. The point is an important one and no doubt before long will be settled ; meantime it is safer to assume that biological treatment does not destroy pathogenic germs.

Experiments at the Leper Asylum at Matunga.

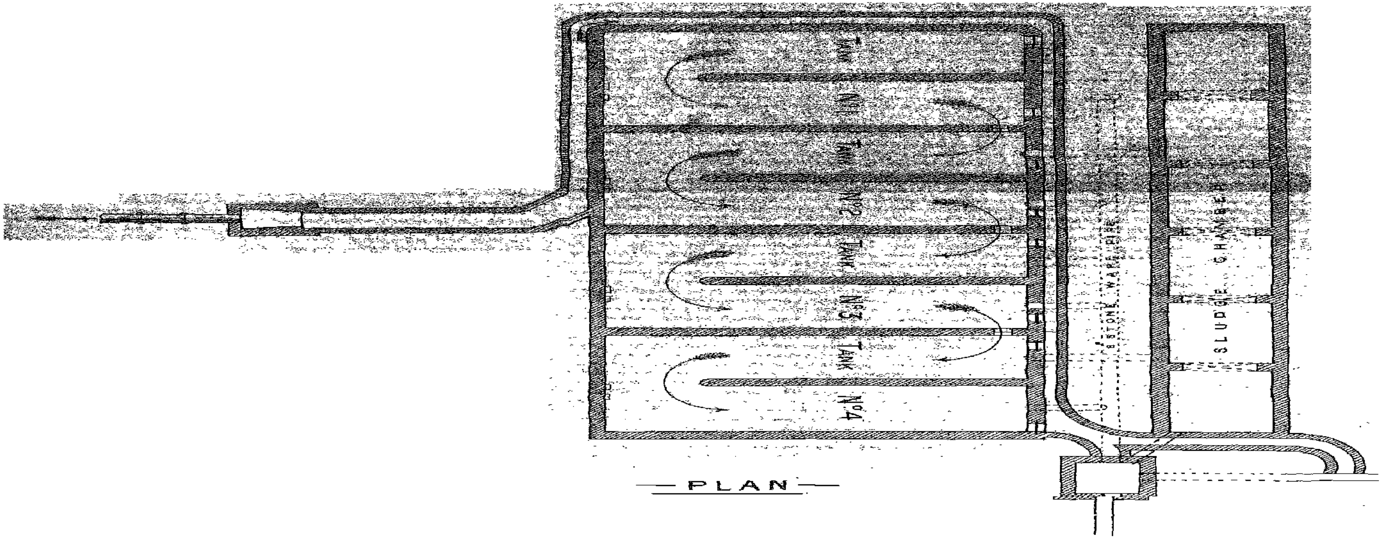
Sewage farm.—Through the kindness of the Chairman of the Matunga Leper Asylum, the Author has been able in the last eight years to make some valuable experiments at the Asylum in regard to sewage disposal. The Asylum lies to the east of the ridge which runs north and south on the harbour side of the Island of Bombay and is about eight miles from the Fort. It is in such a position as prevents its being drained into the main sewerage system of the Island except by pumping and has therefore its own separate system. In the early part of 1901 the Author published a short work called "Notes on Sewage Disposal," which dealt with various experiments made by him at the Asylum from the year 1894 up to that time. It is now proposed to give a brief resumé of these experiments together with

some further results. When the Asylum was constructed in 1891, it was a part of the Author's duty to supervise the drainage arrangements of the Institution. These arrangements consisted of stoneware pipe drains laid from all nahanis and latrines so as to convey the sullage to two large pits filled with rubble stone and located on the outskirts of the Asylum ; but owing to the presence of clay in the subsoil, these pits were unsatisfactory from the beginning and eventually became entirely choked with solid matter, so that the sewage overflowed on to the adjoining land not in the possession of the Asylum. This brought forward complaints from the adjoining land owners, who ultimately gave notice of their intention to apply for an injunction to prevent the Asylum authorities discharging sewage on to their land. This was in 1894, and arrangements were then made to purchase a tract of land adjoining the Asylum on which the sewage matter could be disposed. Originally it was thought that it would be sufficient to dispose of the sewage in its crude state on this land, but this was found to be objectionable and resulted in a nuisance and in the land becoming coated with organic matter, which destroyed its purifying qualities. The fodder crops grown on the land were unwholesome and cattle would not eat them. It then became necessary to devise some means of purifying the sewage before discharging it on to the land. In 1895, the Author, working independently but curiously enough on the same lines as Mr. Cameron at Exeter, experimentally constructed the open Septic Tanks, shewn in Plate 40 and described more in detail later in this Chapter. It should be mentioned, however, that at this time the name "Septic Tank" had not been coined nor had the properties and

Plate 40

Open Septic Tanks

Scale 1/8 to a Foot



Plan

Cross Section

possibilities of such a tank been even approximately ascertained.

The land was at this time laid out as a small experimental sewage farm in plots, averaging about half an acre in area, and so arranged as to be irrigated by the effluent from the Septic Tanks. The channels or carriers for conveying the effluent were lined with half stoneware pipes of 9 inches and 6 inches diameter according to requirements. In 1895 the area was 3·63 acres, but with the extension of the Asylum this has now been increased to 5·92 acres.

The natural soil of the farm was of the least desirable character for cultivation purposes, being yellow clay over-lying muram, but by much ploughing, turning over and irrigation it has been greatly improved, although still leaving very much to be desired. The level of the land on the farm is such that only one-third of it can be irrigated by gravitation direct from the Septic Tanks. For irrigation of the remainder, the sewage effluent is allowed to flow into wells from which it is lifted by Persian wheels, bullocks being used as the motive power. During the dry weather the whole of the daily sewage from the Asylum, nearly 20,000 gallons, is discharged into the Septic Tanks and afterwards disposed of on the farm ; but during the monsoon months in periods of heavy rain, when water is not wanted for the crops, the effluent is allowed to flow away with the storm-water to the sea, it being then inoffensive and practically innocuous.

The crops chiefly grown on the farm are guinea-grass, maize, and jowar with a rotation crop of some pulse or vegetable. Lucerne has been tried but not with any success, the reason being that the plant obtains its

nitrogen from the air by means of tubercles which settle on its roots. If the tubercles do not exist in the soil, the plant will not grow. English vegetables have been grown with considerable success, all attaining a large size. Six crops of maize and jowar are obtained in a year and a cutting of guinea-grass once every month throughout the whole year.

The following figures represent the total returns of fodder grown on the farm for the year 1901 :—

Maize	52·59 tons.
Jowar	49·39 ,,
Guinea-grass	31·33 ,,
Total...	133·31 tons.

As, on an average, only 5 acres were under cultivation during this year, this gives a total return of 26·7 tons of fodder per acre for the whole year—a result which must be considered as very satisfactory. All this fodder has been supplied at market rates to the Health Officer of the City of Bombay for the feeding of the Health Department bullocks.

The labour on the farm, except the supervising staff, consists to a large extent of lepers, who are paid a fair wage for the work they do. Their health is very greatly improved by the regular exercise thus obtained, but their strength is never equal to that of a healthy cooly. The financial success of the farm has been a progressive one. In 1899-1900 the net profit was equal to 21·92 per cent. on the capital outlay, while in 1900-1901 it reached 30 per cent.

The following statement shews the progressive gross revenue and expenditure from 1895, when the farm was first started, to July 1902. Except for the first year, the farm

has always paid its way and furnishes an excellent example of the improvement that will take place in the fertility of a poor land after some years of irrigation with sewage effluent.

Year.	Income.			Expenditure.		
	Rs.	a.	p.	Rs.	a.	p.
1895.	158	7	10	509	12	1
1896.	1,011	12	6	520	13	10
1897.	1,722	2	1	570	8	6
1898.	1,556	2	6	611	5	0
1899.	3,781	12	9	1,057	10	5
1900.	5,167	11	1	2,371	14	5
1901.	7,073	6	11	3,972	8	0
Jany. to July 1902.	6,295	4	5	2,187	1	9

During the eight years the farm has been under irrigation, none of the plots have remained fallow for more than one month at a time, but during 1901 some of the crops shewed signs of failing. Arrangements were then made to burn stable litter upon the ground spread to a depth of 1 foot, the ashes being dug in. This resulted in re-supplying the land with potash and phosphates and the necessary chemical bases and since then quite abnormal crops have been obtained. This is the only sign of failure that has been observed during the time the farm has been in existence.

Considerable doubt existed as to whether the irrigation of sugar-cane by sewage effluent was likely to prove

injurious to the plant and the point has from time to time been freely discussed at Poona and elsewhere. Accordingly, in April 1901, a careful experiment was entered upon, about 200 cuttings of sugar-cane being planted in a small plot on the farm. The trial was made with cane of the variety known in the Bombay market as "surti." The plot was irrigated solely with the effluent from the Septic Tank, four or five times a month, for a period of nine months, no manure of any other kind being applied to it. The crop was good and the out-turn, when it was cut on the 27th January 1902, was 500 canes. This figure, however, does not represent the actual number of canes, for rats appeared to take a great liking to them, and, in spite of all precautions, at least 100 canes must have been destroyed by the time the crop was ready for cutting.

The juice was extracted in the ordinary way by crushing the cane between wooden rollers. It was at once boiled and converted into jaggery or "Goor" by a man engaged in that particular trade, and who was especially brought to the place for the work.

The total quantity of jaggery obtained was $3\frac{1}{2}$ mds. It was of a brown colour with a very sweet taste and crystallized and solidified properly.

A sample of the raw sugar was forwarded to Dr. J. Walter Leather, Agricultural Chemist to the Government of India, and the following is the Analysis of it with his remarks :—

Cane Sugar	69·80
Glucose	13·65
Moisture and dirt	16·55
	100·00

"The sample contained a good deal of dirt, which might with advantage have been screened from the juice before boiling. Otherwise, it is a good raw sugar and better than much which is commonly made by the cultivator."

(Sd.) J. WALTER LEATHER.

The result shews that sugar-cane can be successfully grown under effluent irrigation and the quality is at any rate as good as that ordinarily grown by the cultivators with the aid of the usual solid manures. This experiment should be an encouragement to continue the growth of sugar-cane in larger quantities under similar circumstances.

Septic Tanks.—Plate 40 shews the installation of Open Septic Tanks at Matunga, consisting of a series of four tanks, each 20 feet by 10 feet by 4 feet deep, connected one with the other by an opening 12 inches wide in the dividing wall of the tank at the same level as the inlet to No. 1 tank. Each tank is further divided by a baffle wall for three-fourths of its length and almost making two compartments of it and round which the sewage flows. Each tank is fitted with a loosely adjusted scum board to reduce the surface velocity of the sewage. Any one tank can be cut off from the others by means of wooden stops and closed for cleaning purposes. The whole of the four tanks working together have a total capacity of 3,020 cubic feet or 18,875 gallons; though, as deposit increases, this capacity correspondingly decreases. The surface sewage, when the tanks are fairly free of deposit, takes an average of eight hours to pass through the distance of 160 feet or at a velocity of 20 feet per hour. This average result was obtained

by several float experiments after removing all the scum boards.

The velocity of sewage through a Septic Tank varies with the volume of sewage flowing into it, which is not a constant quantity, and it again varies as the capacity of the tank is reduced by deposit. The surface velocity must not be taken as the average velocity for the whole tank as the ratio between the surface and average velocities varies according to the design of the Tank and the amount of deposit. Parallel to the Septic Tanks and running their whole length is a sludge tank, connected to each Septic tank by means of a 9-inch pipe. The bottom of this sludge tank is 2 feet below the level of the bottom of the Septic Tanks. When it is desired to clean any of the Septic Tanks, it is shut off from the others by closing down the necessary stops in the channel and the sewage and sludge are run into the low-level sludge tank through the 9 inch pipe connection. The sludge is then allowed to settle, the liquid being drawn off by a hand pump, and when the sludge has dried, it is removed and dug into the land which it seems to considerably benefit, for although it has no manurial value, it helps to lighten the soil. The sludge tanks are only used, when it becomes necessary to clean out the tanks, at intervals of about 3 years.

The Asylum has been slightly enlarged since the tanks were constructed, and 20,000 gallons of sewage are now passed through them per day and dealt with satisfactorily. The liquefaction of the solid matter in the sewage discharged into the tanks is very complete and over 80 per cent. of reduction in albuminoid ammonia is attained during the time the sewage is passing through them.

The population of the Asylum is now about 400 and the whole of the sewage finds its way by a regular system of pipes from the washing places, latrines, and dhobi ground to the Septic Tanks, except a small quantity intercepted for experiments with certain filters. In the light of present experience, the design of the Tanks is defective and, if it were necessary to now reconstruct them or to construct others, an altogether different design would be adopted and more suitable baffle walls constructed with openings alternately at the top and the bottom. These tanks, however, have done the work required of them quite efficiently, and considering that they were constructed purely for the sake of experiment in a then unknown subject, their success has been remarkable. A series of observations of temperatures of the air and sewage entering and leaving the tanks, taken over a period of nine months, shew that there is no difference in the temperature of the sewage entering or leaving the tanks and that the temperature of the sewage has no connection with the temperature of the outside air.

The following is the average of several analyses of the crude sewage at Matunga and of the effluent from the Septic Tanks, made by Dr. C. H. Cayley, M.A., M.D., D.Ph., Divisional Health Officer, Bombay.

In Parts Per 100,000.

	Total Solids.	Suspended Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.
Crude Sewage.	64·91	31·83	3·36	1·08	1·62
Tank Effluent.	30·96	8·80	3·35	1·11	0·311

This gives on an average a purification of the sewage equal to 81 per cent. as estimated on the albuminoid ammonia.

In the 8 years the tanks have been working, they have been cleaned out on three occasions only, the first cleaning being after three years' use. It was calculated that up to that time the organic matter liquefied in the tanks amounted to 61 tons. In England it is usually calculated that 50 per cent. of the solid matter deposited in a Septic Tank is disposed of; but the experience at Matunga is that at least 75 per cent. is liquefied.

The Author is indebted to Dr. J. Walter Leather, the Agricultural Chemist to the Government of India, for the following analysis of a portion of the solid matter, removed recently from the tanks at the time of cleaning :—

"Analysis made on 18th February 1902.

Moisture................	65.18
Organic matter.........	9.74
Mineral matter	25·08
Total ...	100·00
Containing nitrogen ...	·56
Do. Sand	13·08
Do. Phospheric Acid	·32

"This material appears to correspond closely in composition to that which Dr. Rideal examined for the Exeter Septic Tank."

(Sd.) J. Walter Leather,

Agricultural Chemist to

the Government of India.

This is an interesting analysis and it will be noted that 72 per cent. of the solid matter, or humus as it is called, remaining in the tanks at the time of cleaning was mineral matter and therefore not further reducible by the bacteria. In average fœces the percentage of organic matter is 86 and mineral 14.

The inference to be drawn from the above is that an even warm temperature has much to do with the proportion of organic matter disposed and left undisposed of respectively by the bacteria, for whereas 24 hours are stated to be required in England for the treatment of the sewage in Septic Tanks, the same work is more efficiently done here in Bombay in 8 hours.

When it is necessary to clean out a Septic Tank, care should be taken to always leave a small amount of deposit in the bottom for the immediate renewal of septic action when the tank is put into operation again. The bacteria will no doubt develop in an absolutely clean tank, but it will take time for them to accumulate to the quantity requisite for the maximum degree of purification.

Too much stress cannot be laid on the fact that the surface or scum of the Septic Tank should not be disturbed, as interference with bacteria means a suspension of their work and in places where heavy rains are frequent, the tank should on this account be protected with a covering.

The following analyses of sewage taken at the point of discharge from No. 2 into No. 3 Tank (see Plate 40) and of the final discharge from the Tank four hours afterwards are very interesting, for the result shows that probably the greater part of the breaking down of the organic matter is done by the bacteria in No. 1 and No. 2 Tanks, and this is further borne out by the fact that in some respects the effluent from No. 4 Tank is inferior to that from No. 2 Tank.

Parts Per 100,000.

	Total Solids.	Suspended Solids.	Chlorine.	Free Ammonia.	Alb. Ammonia
Crude sewage entering Septic Tank, 21st February 1901 ...	64	16	4·00	2·64	·68
Sewage taken from point of discharge of No. 2 Tank, 10th May 1901 ...	44	16	2·3	1·60	·448
Effluent taken from final discharge of Septic Tank, 10th May 1901 ...	36	8	2·3	1·44	·608

The analysis of the crude sewage is given as a guide only, it having been made on a different date from that of the effluents and is, as indicated by the chlorine, not of the same sewage. The point, that it is desired to bring out, is that it is more than probable that at any rate in India the largest percentage of purification is carried out much more quickly than is generally supposed.

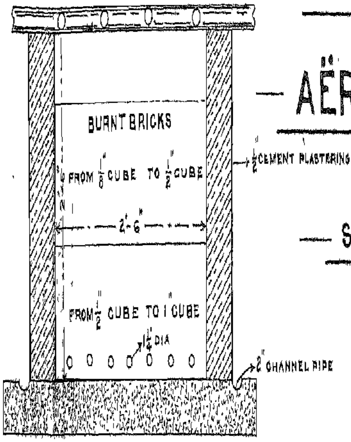
It has been proved by experiments in England that no purification advantage accrues from allowing sewage to remain in a Septic Tank for more than 24 hours and that it is far from being improved by remaining 48 hours. In India the period of maximum purification is probably much less than in England, and further experiments are now being undertaken at Matunga with a view to determine this important point.

Filters.—Various filters have been constructed at Matunga combined with septic and other tanks, and fitted

CONTINUOUS AËROBIC FILTER

SCALE $\frac{3}{4}$" TO A FOOT

— SECTION —



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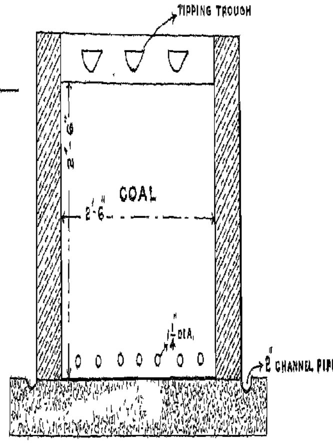
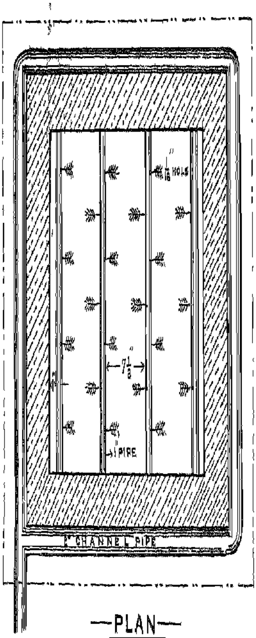
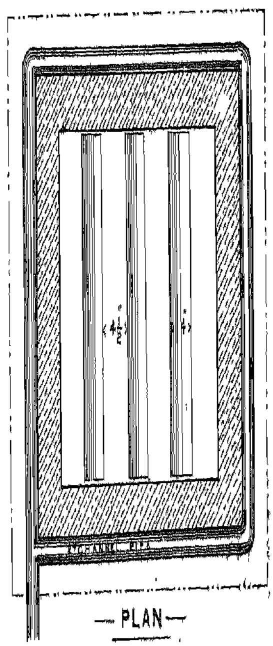




—PLAN—



—PLAN—

with different arrangements for distributing sewage on to their surfaces, and also with several different materials as filtering media. Experiments have been tried with a Septic Tank combined with Aerobic Filters, and with a Septic Tank combined with a Contact Filter, and with a Macerating Tank combined with Col. Ducat Filters.

A Stoddart Filter with a patent "distributor," combined with a Macerating Tank and a Col. Ducat side aerated filter dealing with crude sewage only have also been tried. More recently a series of two Contact beds fitted with Adam's Timed Siphons have been erected to deal with Septic Effluent, as also a Streaming Filter fitted with an Adam's Rotating Distributor. Further interesting experiments are at the present time being carried on with Septic Gas, the gas being collected and supplied to a gas engine working a pump for lifting the Septic Effluent on to the Contact beds.

All these filters, tanks, and modes of distribution of sewage on to filters, and the Septic Gas treatment, etc., many of which are new and interesting, are fully described and commented upon in the following pages.

Attached to the Septic Tanks and shewn in Plate 41 are two small Aerobic Filters, 2 feet 6 inches by 2 feet 6 inches by 2 feet 6 inches, built entirely for experimental purposes. These filters are designed to receive and to purify Septic Effluent at the rate of 250 gallons per square yard per day. The medium used for filtering is in one case burnt brick broken from 1/8th inch to 1 inch cube and in the other English coal also broken to the same sizes.

In the brick filter the Septic Effluent is delivered by three galvanised distributing pipes under a head of

7 inches and having 1/16th inch perforations at intervals of 5 inches. These distributing pipes work fairly well, in spite of the fact that some of the perforations are occasionally closed by floating solid matter. In the coal filter the Septic Effluent is distributed by small tipping troughs which, when full, tip automatically one way and empty their contents on to the filters. This kind of distribution is apt to disturb and ridge the top of the filtering medium especially if it is of fine material. The time of the passage of the effluent through both filters is exactly the same, being from 10 to 12 minutes, and the resultant effluent shews a very high degree of purification, and is in appearance like the purest spring water ; bright, clear and free from all deposit and smell.

The following are the two analyses of the effluents from each filter made by Dr. C. H. Cayley, in February *1901 and in July 1902.*

Parts Per 100,000.

Filter.	Total Solids.	Chlorine.	Free Ammonia.	Alb. Ammonia.	Nitrites.	Nitrates.
Burnt brick effluent taken February 1901 ...	29·33	3·63	0·340	0·106	0·343	3·84
Burnt brick effluent taken July 1902	32·85	2·7	0·024	0·042	Nil.	11·70
English coal effluent taken February 1901	20·00	3·20	0·172	0·065	0·201	6·35
English coal effluent taken July 1902	22·85	2·4	0·010	0·027	Trace.	2·214

The analyses are interesting and shew that the efficiency of each filter has been quite maintained during the 18 months that had elapsed since the first analyses were made.

They have been continuously worked without clearing or being in any way interfered with, since their construction in January 1901. The percentage of purification over the crude sewage admitted to the Septic Tanks is over 90 per cent. and the time taken in the operation is 8 hours in Septic Tanks and 12 minutes in the filters.

Dr. Cayley remarks in regard to the two later analyses that "the effluents were clear and bright with a small trace "of a brownish sediment" and that "the sewage was weak." This latter may be accounted for by the fact that either the sewage was night sewage which is always weaker than day sewage or that there had been rain during the night, which diluted the sewage flowing into the Septic Tanks, for although the Asylum is drained on the "separate" system, some rain water gets into the sewers through the washing places. Such a high degree of purification, as is shewn by the above analyses, is not necessary for an effluent for sewage farming in India, and the amount of purification obtained from a scientifically constructed Septic Tank without further filtering is all that is required, as the land converts the organic matters into those which are necessary for the life of plants, and very quickly does what the filters would do and leaves the effluent in such a degree of purity that it may with safety be allowed to flow where it will.

Neither of the two materials used in these filters for filtering purposes have degraded to any large extent, nor has

any chokage of the filters ensued. Of the two materials, English coal gives the better result and this has also been noticed in England, but no satisfactory explanation has been forthcoming.

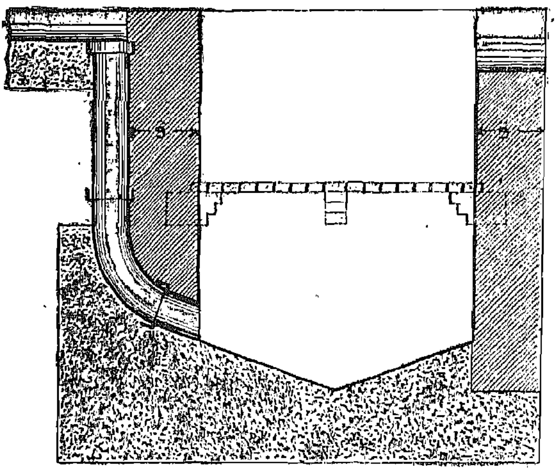


FIG. 32

Fig. 32 shews a small filter for upward filtration designed by the late Mr. W. Santo Crimp, M. Inst. C.E., and called a "Macerating Tank." Sewage is admitted at the bottom of the tank and passes upward through a layer of 1 foot or more of road metal. The solid matter is retained in the bottom and no doubt is there disposed of by anaerobic bacteria as in a Septic Tank. When cleaning is necessary the sewage is passed through the road metal or filtering material the reverse way and the deposit flushed out through a sluice provided for this purpose. This class of tank is useful chiefly for arresting the solids in the sewage, but its purification properties are small, as it is constructed of small size compared with a Septic Tank.

Adjoining the Macerating Tank and combined with it is a filter, 6 feet by 3 feet by 3 feet deep, shewn in Fig. 33, worked on the principle of a Contact Filter. This filter receives sewage after it has passed through the Macerating

Tank, so that it arrives to a large extent free of solid matter. The filtering medium used is coal clinker all broken evenly to

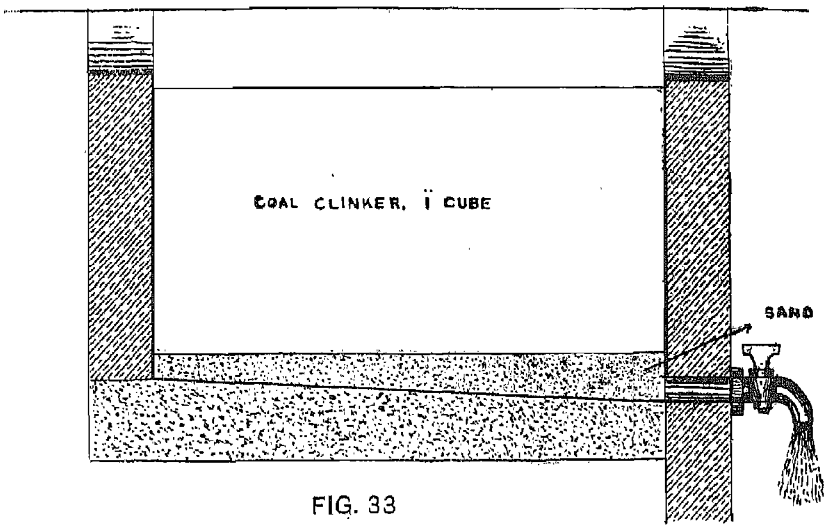


FIG. 33

1 inch cube. Originally 3 inches of river sand at the bottom was tried but this was found to be useless as it was gradually all washed out with the effluent.

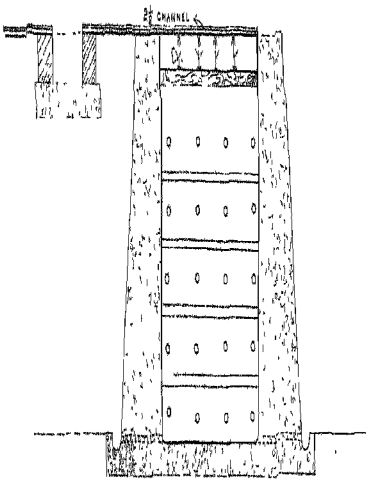
This filter is worked in cycles of 8 hours, that is to say, it is filled in two hours, rests full for two hours, is emptied in two hours and rests empty for two hours. Sewage at the rate of 250 gallons per square yard per day is passed on to the filter, and analyses shew that the purification obtained is 80 per cent. or about the same as with the Septic Tank. This must be considered satisfactory, as the sewage, which has had practically no previous purification, is only in actual contact with the filtering material for an average of four hours. In England filters of this description are frequently built in a series of two so as to provide for two contacts, and sometimes three contacts are considered to be necessary to obtain a satisfactory degree of purification.

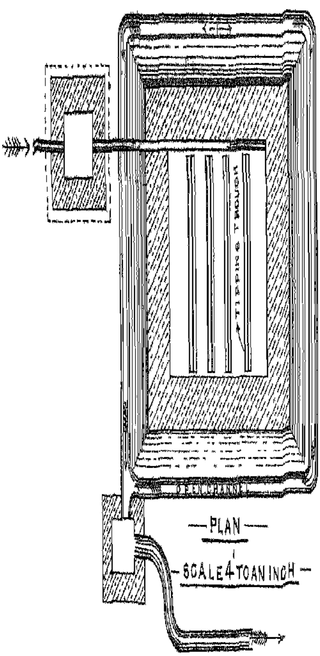
When the filter was constructed in October 1899, its sewage capacity after careful measurement was found to be 41 per cent. of its total cubical capacity. It was again measured some two months afterwards and found to have been reduced to 33 per cent. In July 1902, that is 31 months later, all the contents of the tank were removed, measured, washed and put back again and it was found that the capacity had been further reduced to 31 per cent. or by 2 per cent. only in 31 months, and there was no degradation of the clinker filtering material. This is a very interesting result, because one of the apparently insurmountable difficulties with this class of filter in England at present is the rapidity with which it sludges up, and the cost of constantly cleaning such a filter of large area is a very serious item in the expense of a biological installation. There is no doubt that the Macerating Tank which retained the greater part of the solids in suspension, helped largely to the good result obtained at Matunga, and it goes to shew that this kind of filter can be worked without serious sludging up for a considerable period, if, in some way, the greater part of the solids in the sewage are arrested and not passed on to the filter. If the degree of purification attained after passage through this filter were insufficient under any particular circumstances, the additional purification desired could be attained by further filtration through a second or even a third similar filter.

Combined also with the filter, above described, is a small covered Septic Tank, constructed of lime concrete, the internal dimensions of which are 5 feet by 4 feet by 3 feet. This Septic Tank is worked under similar conditions to the Open Septic Tanks and supplies the Contact Filter with effluent alternately with the Macerating Tank.

8 FT DUCAT FILTER

SECTION



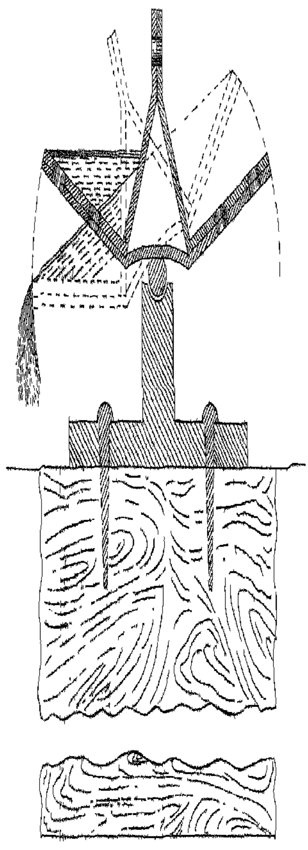


PLAN

SCALE 4 TO AN INCH

SECTION

OF TIPPING TROUGH



HALF FULL SIZE

It has been now working continuously for 18 months (July 1902), and the results obtained are on a par with those with the Open Septic Tanks, the analysis shewing a purification of 81 per cent. This result agrees with the experiments made with covered and open Septic Tanks in England, which shew no appreciable advantage either one way or the other.

Three continuous Aerobic Filters on Col. Ducat's principle have been erected at Matunga. For descriptive purposes these filters are numbered one, two and three, and they have all now been working continuously from two to three years. The special features of a Ducat's Filter are (1) the side aeration, by which air is passed into the body of the filter for the supposed better development of the aerobic bacteria, and (2) the direct reception of crude sewage without any previous treatment.

Plate 42 gives a drawing of No 1 filter, which is 5 feet by 5 feet by 8 feet deep, or nearly three square yards in area, which at 250 gallons of sewage per square yard is capable of dealing with 750 gallons per day. The filter is supplied with sewage obtained from a bathing place and a latrine, used only by a colony of 18 sweepers attached to the Asylum. Some months ago, a water meter was fixed on the supply pipe which shewed that the sweepers were using 40 gallons of water per head per day or 720 gallons in all, so that the filter was then getting its full complement of sewage. The water-supply has since been reduced to 10 gallons per head per day and the comparative analyses of the effluents will be given later on in this Chapter.

The side aeration of this filter is much less than arranged for in Col. Ducat's Standard Absaf Filter,

where the walls are honey-combed with pipes. At alternate heights of 1 foot, pipes with butt joints are laid cross ways through the filter, the joints of the pipes being about ¾ inch apart, and meeting the pipes in the wall to enable the outside air to pass freely into the centre of the filter.

The filtering medium used is "over-burnt brick," broken from ⅛ inch to 1 inch cube, the smallest being at the top. This material is too fine for a filter dealing with crude sewage only and though the ultimate results have been satisfactory, it is advisable to always have the top layer at any rate of coarser material, so that the solid excreta, etc., may be the sooner disposed of and also that the sewage discharged on to the filter cannot "head up," as has here been the case on several occasions. The sewage is discharged on to the filter by means of tipping troughs as shewn in Plate 42.

These tipping troughs are automatic, and are balanced and hung in grooves, which require to be kept well lubricated. They tip alternate ways and empty as soon as they fill by overbalancing. They are satisfactory, except for the objection before stated, that with fine filtering material as a top layer they ridge that material in front of the discharge from the tippers.

The filter has, during the three years of its existence, given universally satisfactory results. Once only during that time has the top foot of the filtering material been removed and washed. It was then found by measurement that the degradation of the burnt brick had amounted to 50 per cent. of its original bulk and this is an undoubted defect in this class of filtering material.

The following analyses of crude sewage and of the effluent taken in December 1900 and of the effluent in July

1902 shew the purification obtained in the 45 minutes which the sewage takes to travel through the filter :—

Parts per 100,000.

	Total Solids.	Susp. Solids.	Chlorine.	Free Ammonia.	Alb. Ammonia.	Nitrites.	Nitrates.
Crude Sewage, December 1900 ..	380·67	310·67	5·73	2·531	1·253	Nil.	Nil.
Effluent, December 1900, 240 gallons per square yard...	54·67	Nil.	5·367	0·077	0·067	0·625	13·555
Effluent, July 1902, 60 gallons per square yard ...	·85	Nil.	3·85	0·064	0·034	Trace.	28·8

The effluent in both cases was exceedingly bright and clear, free from any smell and shewed that a very large amount of purification had taken place and that there was also very little free ammonia, practically the whole of the nitrogenous matter having been purified into nitrates.

That the filter has maintained its purification properties the July effluent undoubtedly shews.

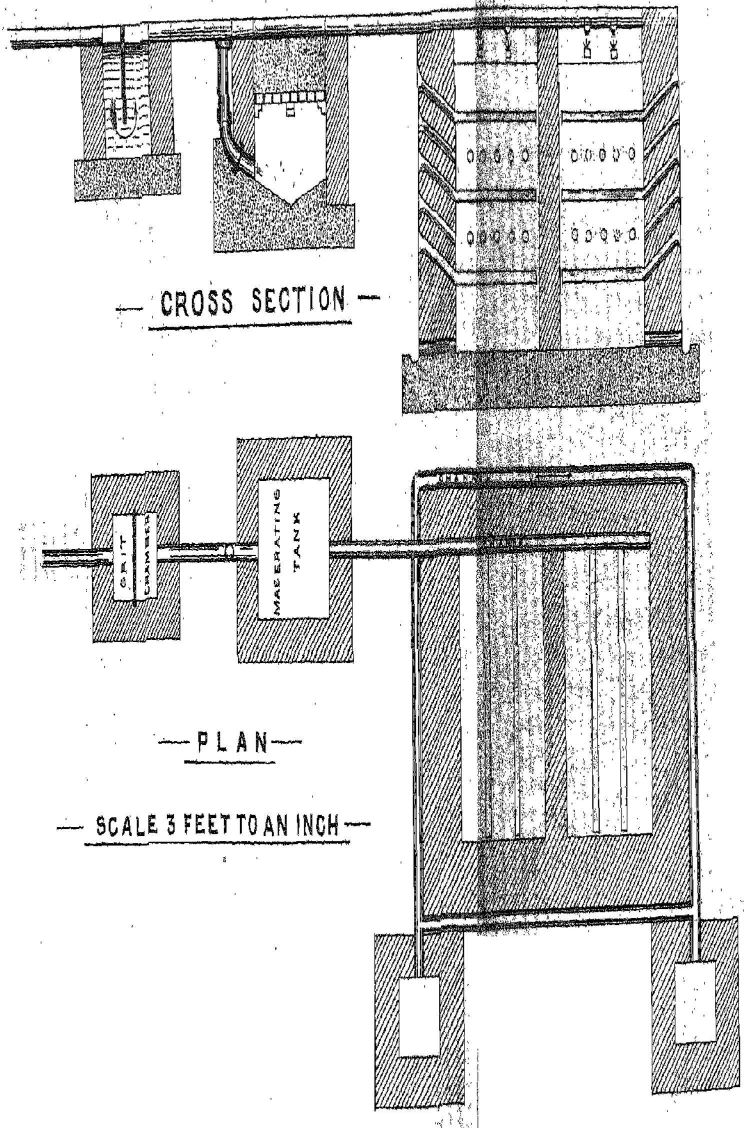
The experiments made at Leeds under the supervision of the Royal Commission on Sewage Disposal prove that side aeration is not necessary in a Continuous Filter, provided the surface of the material is kept open and clean, and that there is practically no difference in the purification obtained in an aerated and a non-aereted filter. Such aeration is always from the top, the air naturally following the sewage into the filter. As an example of the bacterial

efficiency of this filter it may be stated that a large dead rat was placed in the filter on one occasion and covered with about 1 inch of filtering material. When examined four days afterwards the whole of the rat had been broken up by the bacteria and had disappeared leaving but a few fragments.

Filters Nos. 2 and 3 have been constructed alongside each other, as shown in Plate 43, and each measures 5 feet by 3 feet by 5 feet in depth, or 3 feet less in depth than the minimum recommended by Colonel Ducat. The sewage supplied to them is obtained from a latrine and a bathing place, erected solely for the use of one of the wards containing 24 adults. It first passes through a small Macerating Tank, 2 feet by 2 feet by 3 feet in depth, and is then discharged on to the filters. The filtering medium used in No. 2 filter is burnt brick broken from ½ inch to ¼ inch cubes, and that in No. 3 is English coal broken to the same size. For months, the effluents from both filters were turbid and cloudy, but in time they gradually cleared and have now been for some months universally bright and clear. These two filters have been in continual use for more than two years and the result goes to prove that the depth of the filter of Colonel Ducat's design may quite well be less than the 8 feet stipulated by him and that with only 5 feet of filtering material a very satisfactory effluent can also be obtained. It must be noted, however, in regard to these two filters that the sewage is first passed through a Macerating Tank, where most of the solids in suspension are arrested, though no particular purification takes place.

The following analyses made by Dr. Cayley in July 1902 show that the quality of the effluents is exceedingly

5FT DUCAT FILTER



CROSS SECTION

PLAN

SCALE 3 FEET TO AN INCH

good ; a comparison with No. 1 filter can hardly be made, as that receives crude sewage :—

Parts per 100,000.

	Total Solids.	Chlorine.	Free Ammonia.	Alb. Ammonia.	Nitrites.	Nitrates.
No. 2 Filter, Brick	65·7	4·64	0·077	0·124	Nil	31·00
No. 3 Filter, Coal	70·0	4·86	0·009	0·045	Nil	39·857

Both effluents were bright and clear and free from any smell and deposit. It will be noticed that the result obtained from the coal-filtering medium is again superior to that from the brick, the sewage in each case being the same and supplied at the same time.

Two samples of effluents taken on 10th March 1901 and kept in stoppered bottles until July 1902 have retained their clearness and brightness without smell of any kind, showing that the purification was complete and that there was no secondary putrefaction.

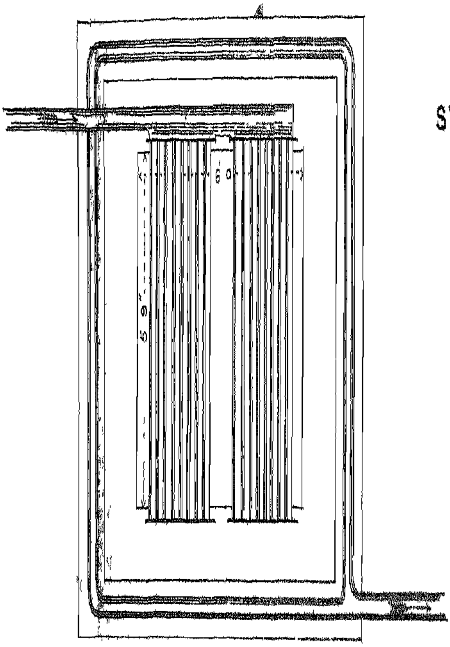
The results obtained at Matunga with Colonel Ducat's filters have been uniformly good, but, in any installations built in the neighbourhood of dwellings, it is desirable to give the sewage some previous treatment, such as passing it first through a Macerating Tank to arrest solids and fœcal matter, for the reasons that an open filter receiving crude sewage must always be slightly offensive, as fœcal matter is likely to lie on the surface for some hours before being entirely broken up. Matunga has been more fortunate with a Ducat filter than Leeds, where the discharge of crude manufacturing sewage on to a similar filter was found to be a distinct failure, though, when worked with a Septic

Tank effluent, the result was more favourable. Temperature and the class of sewage are probably responsible for the better result here. This small installation of a combined Macerating Tank and Ducat filter is an example of what might confidently be expected from a similar construction on a much larger scale, but it is recommended that, to start the filter and get it rapidly into good order, it should be at first supplied with crude sewage so as to immediately charge it with the necessary organisms to get it into full bacterial action. For England Colonel Ducat has specified that the sewage should be heated before being delivered into the filter, but that process, whatever its advantage may be in England, is certainly not necessary in India.

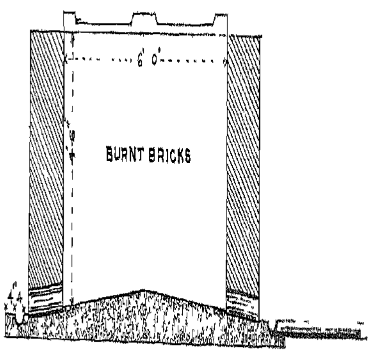
After the experiments carried out with Continuous filters in England, side aeration cannot be considered a necessary or even a desirable feature in a filter, therefore that special peculiarity of the Ducat filter may be dismissed. Again, the two filters above described show, as already pointed out, that Colonel Ducat's minimum depth of 8 feet is more than is necessary. This is very important as a loss of 8 feet in head is far more often impossible to afford without pumping than that of 5 feet. The filter has undoubtedly purified crude sewage very satisfactorily, but probably in India any Continuous filter scientifically constructed would do the same.

Stoddart's Continuous Filter.—Adjoining the two filters last described and sharing the same sewage with them has been erected another filter, 5 feet by 5 feet by 4 feet deep. The special feature of this filter, which was first designed by F. Wallis Stoddart, F.I.C., F.C.S., Public Analyst for Bristol, is its "Distributor," but in other ways it is just an ordinary continuous filter with

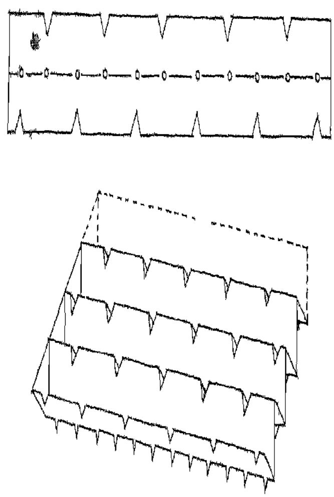
STODDART'S FILTER WITH PATENT DISTRIBUTORS



PLAN



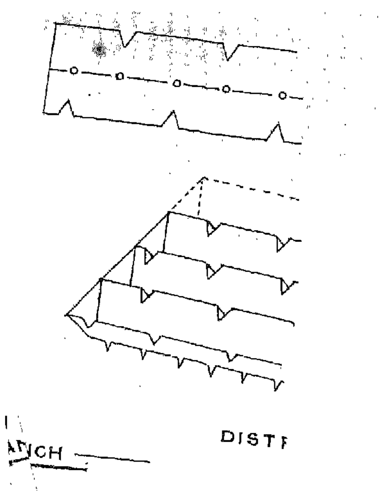
SECTION



DISTRIBUTOR

SCALE 3 FEET TO [illegible]ICH

'S FILTER WI



closed sides. It is not a filter on to which it would be statisfactory to discharge crude sewage; such sewage should either be closely screened or passed through some previous treatment before it can be with success applied to a "Stoddart's Distributor." Several of these filters have been working near Bristol for a considerable time, with, it is stated, quite satisfactory results. Plate 44 shows the patent "Distributor;" it is made of thin galvanized iron and consists of a number of narrow gutters arranged at right angles to the supply channel, and rests upon its margin, and upon a suitable support at the other end. The level of the "Distributor" is so arranged that the sewage from the channel flows equally into all the gutters of the "Distributor." In these gutters there are a series of holes, in which nails are loosely inserted and sewage drips through these holes continuously in small drops and falls on the filter after the manner of rain. Besides these nail-holes, slots are cut in the top of the corrugations of the gutters, so that in the event of the nails rusting in, or clogging, another means is provided for the sewage to pass on to the filter. The "Distributors" are made in sections 8 feet long by 1 foot 6 inches in width, and are placed about 9 inches apart on the filters, and 3 inches above the filtering medium. The nails in the bottom of the gutters should always be made of zinc and not of iron, as the latter naturally soon rust. Copper nails should not be used as they set up galvanic action. Those used at Matunga have worked satisfactorily and no serious clogging has occurred in them.

The "Distributors" work by gravitation and require no head. This filter has closed sides and the filtering medium is burnt brick, broken to ¾ inch cube. It is

combined with a Macerating Tank as are the Ducat filters Nos. 2 and 3, and has been working more or less continuously for 12 months, but still the effluent is turbid and unsatisfactory. This suggests that when a Macerating Tank is used for the previous treatment of sewage, in combination with a Continuous filter, many of the organisms necessary to the satisfactory working of such a filter are kept back with the solid matter. A Macerating Tank is, however, an economical and convenient arrangement and is not so cumbersome as a Septic Tank, but in starting such a combined installation, some crude sewage should be, for a short time, discharged on to the filter so as to supply the necessary bacteria and, so to speak, seed it.

This conclusion is further borne out by the following analysis of an effluent made by Dr. Cayley in July 1902, when the filter had been in use for 12 months :—

Parts per 100,000.

	Total Solids.	Chlorine.	Free Ammonia.	Alb. Ammonia.	Nitrites.	Nitrates.
Stoddart's Filter	57·1	4·57	1·15	0·56	·736	1·77

Dr. Cayley says "the effluent was thick, dirty-looking "and had a bad smell. There was a considerable amount "of suspended organic matter, *i.e.*, unconverted sewage, "equalling 9 grs. per gallon. The free ammonia was "enormously high, the figures above being only approxi- "mate as the amount was too great to allow of a proper test. "Very little nitrification has taken place. This is a very bad "effluent. This effluent was evidently in a high state of "putrefaction and continued to decompose after 24 hours in "a bottle."

There is therefore little real purification in this effluent: a reduction of the solids being apparently all that has so far been achieved.

Another analysis made by Dr. Cayley, on 2nd October 1902, shows very little improvement on the previous one. In this instance crude sewage as well as the effluent from the filter were analysed.

	Crude Sewage.	Effluent.	
Free Ammonia ...	10·640	13·320	Parts per million.
Alb: Ammonia ...	5·2	3·540	Do.
Chlorine	3·3	3·4	Grains per gallon.
Total Solids	74	38	Do.
Dissolved Solids ...	32	......	Do.
Suspended Solids ...	15	......	Do.
Nitrites	*Nil*	Trace.	Parts per 100,000.
Nitrates	*Nil*	0·9	,,

"A very poor effluent containing some solid fœcal matter, as well as being thick and having a strong smell."

There is little improvement in the effluent during the three months' interval between the two analyses, and besides the reasons previously given, it is possible that the less depth of the filtering material, this filter being only 4 feet in depth and the Ducat's filter alongside being 5 feet, has something to do with the continuous indifferent results obtained.

It is also more than probable in a filter receiving sewage, as this does, that the covering up with plates of

considerable area of the surface of the material and the delivery of the sewage from the nails on to exactly the same spot day by day may have something to do with the poor results obtained. Whatever, however, may be the reason, the fact remains that after 15 months' trial the effluent leaving the filter is still in a putrefactive condition.

It will be kept in view that the sewage supplied to the two 5-foot Ducat filters and the Stoddart's filter is exactly the same, being supplied from the same channel with branches to the different filters.

With the high temperature in this country, a filter should be in full working order in a month, provided it has some previous anaerobic treatment, but, if sewage is only screened or passed through a Macerating Tank, the probability is that it will be some months before it gives a satisfactory effluent.

An interesting experiment was made with the Stoddart and Ducat filters by removing the Stoddart Distributors from the former and placing them on the latter, and removing the tippers from the latter and placing them on the former. This experiment resulted in an almost immediate improvement in the Stoddart filter effluent and a corresponding decrease of purification in the Ducat filter effluent, which had been previously universally bright for many months, and which almost immediately commenced to show signs of opalescence.

On the 26th of October, Mr. G. Midgley Taylor, M.I.C.E., F.C.S., made an estimation of the oxygen absorbed by the sewage entering the Ducat and Stoddart filters, and by the effluents discharged from each of them, with the following results :

Parts per 100,000.

Crude sewage	1·12	Oxygen absorbed in 4 hours.
Effluent from the Stoddart filter	0·70	,, ,, ,, ,,
,, ,, Ducat filters ...	0·12	,, ,, ,, ,,

This confirms the strong probability previously mentioned that the covering of the surface of the filter with plates, of the description of a Stoddart distributor, is deleterious to the working of the filter, and tends to prevent air passing into the filter from the surface, which is a necessity in a filter of this description. The previous analysis of the effluent of the Stoddart filter made by Dr. Cayley showed that effluent to be in an advanced state of putrefaction; the latter result therefore is a great improvement in purification.

Of all the combinations above described, there is little doubt that a Septic Tank combined with a continuous filter gives the purest effluent and an effluent, which is in many ways actually better than much of the water considered to be potable in India. But the process under this combination is a comparatively long one, even in the climate of India, as it takes between 8 and 9 hours to be complete.

The combination of the Macerating Tank and the 5-foot Ducat filter has been very successful at Matunga, the process taking only some 25 minutes, that is, five minutes through the Macerating Tank and twenty minutes through the filter; but it has the drawback, and it is rather a serious one, of not giving a satisfactory effluent ordinarily, until some months after it has started. It is doubtful whether a Ducat filter by itself dealing with crude sewage should be recommended for use in a large way. It has been eminently successful at Matunga, dealing only with

pure domestic sewage, but for use on a large scale, some previous treatment of the sewage is desirable for the reasons previously given.

As pointed out, land in India is generally available for sewage farming, and consequently nothing more than Septic treatment of the sewage is there necessary. Such a purified sewage, as is obtained from the combinations described, is not worth the expense necessary to obtain it, and the extra purification gives no special advantage over the Septic effluent, when it is to be applied to the irrigation of crops. Effluent from the various combinations has been several times tried upon the crops at Matunga, but the result was not commensurate with the expense of building the filters.

Of all the "Distributors," probably some form of circular sprinkler gives the best results. All tipping troughs have the fault of ridging fine filtering material. The orifices in fixed pipes are liable to choke, but this choking does not apply to so great an extent to rotating arms, the Adam's type of which has given satisfaction at Matunga.

The best filtering medium used at Matunga has been coal clinker. "Over-burnt brick," after being in use for some months, degrades badly, and to a lesser extent so does English coal, but if clinker is carefully picked, there will be no degradation even after years of use.

The Author has had the opportunity of reading the able and interesting paper by Major Ernest Roberts, I.M.S., published in "Scientific Memoirs by Medical Officers of the Army of India," Part XII, 1901, but the limits of this chapter only admit of its being very briefly referred to.

The biological deductions recorded by Major Roberts are not altogether in agreement with those ascertained in

Bombay. Major Roberts has laid considerable stress on the necessity of providing three distinct stages for the purification of sewage. First, anaerobic through a Septic Tank, either closed or open, or by upward filtration on the Scott-Moncrieff plan; secondly, intermittent downward filtration, and thirdly, filtration through porous arable land. He also states that it is undesirable to depend solely on downward filtration, and recommends a combined Scott-Moncrieff and Intermittent Downward Filter for Cantonments.

The experiments at Matunga have now lasted for eight years, and though the sewage treated is dilute and in quantity only 20,000 gallons per day, still the opportunities for observing filtration results have been greater than elsewhere in India. Further, although the sewage flowing into the Septic Tanks is dilute, that supplied to the Ducat Filter is not, it being equal to only 10 gallons per head.

One of the very prominent results demonstrated at Matunga shews that an eight hours' purification in a Septic Tank and a subsequent 15 minutes' passage through an Aerobic Filter (*i.e.*, two processes only) is sufficient to give a very high purification result. Also that sewage passed through a Macerating Tank, which is an improvement on a Scott-Moncrieff Upward Filtration bed, does not give immediately satisfactory results, as has been shewn earlier in this Chapter in regard to the 5-foot Ducat and the Stoddart Filters.

Major Roberts states that the "Dibdin, Ducat, and "Absaf processes are entirely unsuited to the concentrated "sewage of Cantonments and of Natives, even with the "most extravagant preliminary dilution with water."

The reverse has been the experience at Matunga, where an 8-foot Ducat Filter dealing with crude sewage derived from a colony of sweepers has been working continuously for two years. The amount of water (originally 40 gallons per head and recently 10 gallons per head) supplied with the sewage to the filter is measured by meter, so that the extent of dilution is not open to question, and the success of the filter has not been exceeded in any installation that the Author has seen. There has been no appreciable choking in the body of the filter, neither was there any trouble at the start, as in about 6 weeks it was in good working order.

The opinion of Major Roberts that a Septic Tank is inferior in purification properties to an upward filtration bed is not borne out by the experiments in Bombay. But even if this were not so, it must be kept in view that in dealing with a large installation for purifying sewage on biological principles, the cost of providing an Upward Filter would be much greater than that of a Septic Tank dealing with the same amount of sewage. Also the extra cost of cleaning the filtering medium from time to time would be a grave consideration while the sludge in a Septic Tank is very easily removed.

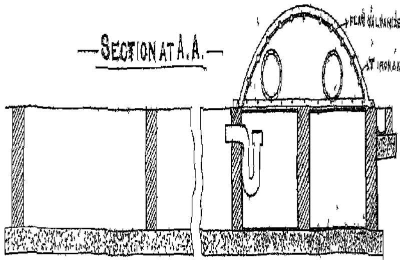
The Author visited England in the summer of 1901, when he had exceptional opportunities of observing the experiments of sewage disposal being conducted there, and decided on his return to make some further experiments at Matunga with Septic Tank Gas, Contact beds, and a Streaming Filter. With this end in view, the No. 1 tank of the Septic Tanks was covered with a galvanised iron gas tight cover as shewn in Plate 45.

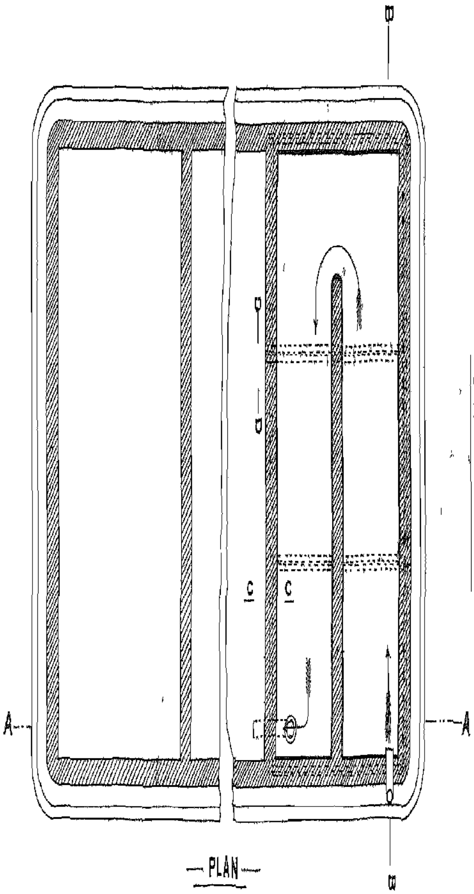
PLATE 45

COVERING OF A PORTION OF THE SEPTIC TANK AT MATOONGA

SCALE 6 FEET TO 1 INCH.

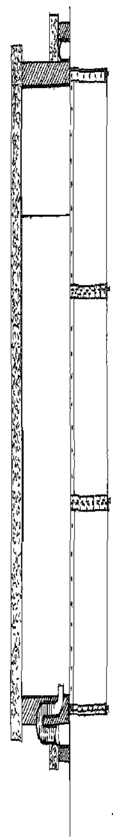
SECTION AT A.A.

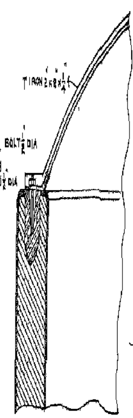




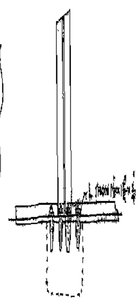
PLAN

SECTION AT B.B.





ENLARGED SECTION AT C.C.



ELEVATION AT D.D.

SCALE 1/2" TO ONE FOOT.

It was decided to have a metal covering to the tank, because the experience at Exeter has shewn that a concrete or masonry cover cannot be made gas-tight. The tank was slightly altered to the extent of its inlet and outlet being trapped with a 12-inch seal. Even with a galvanized iron cover, much trouble was experienced in keeping it gas-tight, and not until the joints had several coatings of pitch, was it found satisfactory. At one end of the cover two inspecting doors are fixed to give access to the tank, when necessary.

The Septic effluent, after it leaves the fourth Septic Tank, instead of passing on to the sewage farm or to the different wells for irrigation purposes, is led by an open channel and a 6-inch stoneware pipe drain to a sump as shewn in Plate 46. In this sump is fixed a 3-inch centrifugal pump of the ordinary type. The sump is a brick chamber rendered with cement and is 4 feet in diameter by 6 feet deep.

For operating this pump, an Otto gas-engine, ½ H.P. Nominal, has been provided, which is capable of developing 3 Indicated H.P. with a consumption of 22 C. feet of coal gas per H.P. per hour, but as it is intended to work this engine with Septic gas, the power developed will be about 50 per cent. less for the same consumption. The gas engine is fitted with an ordinary pattern tube ignition heated by a Bunsen burner. The centrifugal pump lifts the Septic effluent to a high level iron tank fixed about 10 feet above the ground, whence it gravitates to the Contact beds and Streaming filter, hereafter described, through a 2-inch galvanised iron pipe.

The Septic gas to work the above mentioned engine is conveyed by a 1-inch galvanised iron pipe from the cover

of the Septic Tank to a gas-holder as shewn in the above Plate.

The gas-holder is 5 feet in diameter and 4 feet high and is made of 1/8th inch sheet iron. It works in an underground circular brick chamber 5 feet 3 inches in diameter and 4 feet in depth, thus leaving 1½ inches of space all round the gas-holder. Three iron pillars are erected on the top of the brick chamber, each having a pulley at the top and a guide on the side facing the holder, on which works a wheel attached to the top of the holder to keep it in an even position while rising or falling. The gas holder is supported by three chains, each passing over one of the pulleys, and having a counter weight attached at the other end. A pipe one inch in diameter is led from the gas-holder to the engine as shewn in the Plate, while a similar pipe is led from the holder to two incandescent lamps.

The gas-holder is at first lowered right down to the bottom of the masonry chamber, which is then filled with water, the air being expelled through the pipe supplying the gas to the engine. Additional weights are then put on the outer ends of the chains, so as to slightly raise the gas-holder. As air cannot enter through the water to fill in the space in the holder thus raised above the water level, a partial vacuum is formed in the space, which causes a suction in the pipe from the Septic Tank drawing in the gas from the same. As the gas accumulates in the holder, the latter continues to rise. When it has risen sufficiently high, the additional weights are taken off and placed on the top of the holder, thus putting the gas contained in it under compression, and forcing it into the engine, a check valve placed on the supply-pipe preventing any

back pressure to the Septic Tank. It will be hereafter necessary to erect a similar gas-holder to that now in use so that there may be no interruption in drawing off the gas while the gas engine is working. The procedure will then be to utilise the gas in one holder while the other is filling and *vice versa*, an uninterrupted supply of gas being thus obtained.

A similar experiment with Septic gas has been made at the Exeter Sewage Disposal Works at Belle Isle by Mr. Donald Cameron, M.Inst.C.E., the late City Engineer, and there the Septic gas is drawn from the cover of the Tank by an aspirator or fan and supplies the power for working a gas engine and is also used for illuminating purposes. It is said that at Exeter, roughly, 1 cubic foot of gas is obtained per head of population per day at an average temperature of about 55°.

Dr. S. Rideal, who analysed the gas at Exeter on two occasions, gives its composition as follows :—

	Percentages by volume.	
Carbonic Acid	0·3	0·6
Marsh Gas............................	20·3	24·4
Hydrogen	18·2	36·4
Nitrogen	61·2	38·6
Total ...	100·0	100·00

Broadly speaking, it may be said that the gas given off from a Septic Tank contains on an average 20 to 24 per cent. of Marsh gas, and 18 to 36 per cent. of Hydrogen, or, say, altogether an average of 50 per cent. of combustible gases; so that the quantity of Septic gas necessary for each brake horse-power for working a gas engine would be double that of ordinary coal gas.

An analysis has been made by Major Collis Barry, I.M.S., Chemical Analyser to Government, of the gases collected in Septic Tanks at Matunga.

The following is the result of this analysis :—

Carbonic Acid	5·23
Marsh Gas	21·25
Hydrogen	13·52
Nitrogen	60·00

It will be noticed that the composition of the gas closely corresponds with the first analysis made by Dr. Rideal of the gas from the Exeter Works. An important difference is, however, apparent in the percentage of the Carbonic Acid Gas, which is much larger in the Matunga gas than at Exeter. This is no doubt due to the difference in temperature of sewage. Carbonic Acid Gas is to a certain extent soluble in sewage, the amount which the sewage can contain being dependent upon its temperature. In order to render the gas at Matunga suitable for burning or working the gas-engine, it has been necessary to pass the gas over quick-lime so as to absorb the excess of Carbonic Acid Gas, which it must be noted does not only dilute the gas like Nitrogen, but renders it incapable of satisfactory combustion.

The whole of the arrangements for experimenting with Septic gas at Matunga were completed early in September 1902, but owing to a variety of causes it was the beginning of October before much gas was collected. During September a great quantity of rain fell and the sewage was so dilute and the tanks so disturbed that practically no gas was evolved.

It has been the experience at Matunga that during heavy rain, owing to the dilution of the sewage and the

disturbance of the surface of the tank by falling rain, the purification of the sewage for the time being is practically stopped. In the ordinary weather at Matunga gas generates very quickly in the first tank, and it is easy to produce a flame on the surface. This effect of wet weather was also noticed at Exeter and referred to by Mr. Donald Cameron in his evidence before the Royal Commission on Sewage Disposal (*vide* para. 1935).

The evolution and quality of gas depends on the following conditions :—

(*a*) the temperature of the atmosphere ;

(*b*) the rate of the inflow of the sewage ;

(*c*) the dilution and the quality of the sewage.

The amount of gas produced will also depend on the quantity of nitrogenous and non-nitrogenous elements present in the sewage and undergoing the necessary chemical disintegration.

Major Ernest Roberts, I.M.S., in his paper before referred to, states that with the natives of India the unabsorbed proteid from vegetable foods amounts in the excrement from 10 to 20 % of the total ingested, and that from 30 to 50 % of the cellulose leaves the body in its integrity.

Professor Sims Woodhead, M.D., however, stated in his evidence before the Royal Commission on Sewage Disposal that, in the ordinary domestic sewage, the nitrogenous constituent of the sewage is always relatively small, the greater bulk being non-nitrogenous cellulose or the like, and that that cellulose is converted into Carbonic Acid and marsh gas. It would appear from this, with other things being equal, that the gas obtained from the sewage in the East should be equal in amount to that obtained from the

sewage in the West, but it must be noticed that with an increased temperature an increased quantity should be obtained.

Both Mr. Donald Cameron and Mr. W. J. Dibdin in their evidence regarding Septic gas before the Royal Commission on Sewage Disposal, stated that the gas did not accumulate so as to give pressure in the roof of the tank, and that this was proved with delicate pressure gauges. This has also been the experience at Matunga. It was found there that if the gas was not removed from the roof of the tank, which is gas-tight at Matunga, the purification almost entirely stopped and proceeded in the second tank, which in its turn commenced to evolve gas.

Another reason pointing to the fact that the gas is not under pressure in the roof of the tank, is that the gas is unable to lift the holder when the latter is equipoised, and it is only when the gas-holder is placed under suction that the gas can be removed from the cover of the tank. A suction pump attached to the outlet pipe of the cover readily removes a quantity of gas. Marsh gas is inodourous, but the gas at Matunga has a faint smell, not unlike coal gas.

The erection of the gas-holder was completed early in September. Owing to continuous rain, however, but little gas was evolved from the sewage until the 24th of the month and then for a few days the gas-holder only filled once, but after the 28th of September, gas was evolved more freely, and from that date until the 9th of October, *i.e.*, 12 days, the gas-holder filled three times in the 24 hours, thus producing 180 c.ft. of gas per day.

After that date owing to better management of the gas-holder, the gas produced averaged 200 c.ft. per day, but from the 17th of October an increased volume of gas was

evolved, and 300 cubic feet per day were registered. This result was being obtained with an average temperature of sewage of 86°F. No doubt, the amount of gas would be reduced in cooler weather.

On lighting the Septic gas at the open end of a ¾ inch pipe, it burnt quite freely without colour, but on passing it through an incandescent burner of the kind usually used with coal gas, the gas refused to burn. Examination showed that the reason of the failure was the admission of too much air into the Bunsen burner. A paper cover was made to cover the holes in the burner so as to regulate the admission of air, and it was found that by reducing the amount admitted, the gas burnt fairly well. It was evident, therefore, that with gas of the composition evolved at Matunga, an ordinary Bunsen burner admits too much air and that careful regulation is required.

Attempts to work the gas-engine have so far proved unsuccessful, chiefly owing to the inability to burn the gas satisfactorily in the ignition tube chamber. Experiments are still being conducted to regulate the pressure of gas and amount of air admitted to the burner. It has been proved that the regulation of pressure is the main factor to be studied in working a gas-engine with Septic gas.

In heating the ignition tube a low pressure is necessary, as the gas, if passed in at a high pressure, refuses to burn altogether, while, on the other hand, high pressure is necessary after the ignition tube has been heated to get a sufficient pressure in the gas bag to obtain an explosion. A small throttling valve is necessary on the gas supply-pipe to obtain these variations of pressure.

By closing the air holes in the Bunsen burner altogether the gas burns freely at the top of the ignition

tube, and by slightly opening the air holes the flame flashes back to the proper burning point, and after 15 minutes the ignition tube is heated to dull red.

Contact Beds.—Contact beds are so called, because sewage remains in them in contact with the filtering material for some length of time. As is described earlier in this Chapter, the Septic effluent at Matunga flows by gravitation from the raised iron tank, above referred to, to a series of two Contact beds through a 2-inch pipe.

Before discharging into No. 1 bed, the Septic effluent is discharged into a measuring tank, as shown in Plate 46. This measuring tank holds, when full, 2,500 gallons of effluent, the exact quantity required to fill each Contact bed in turn, and has a recorder, which registers its discharges. It is fitted with a siphon which automatically discharges its contents, when full, with rapidity, which is found by experience to be of great importance.

The size of each Contact bed is 30 feet by 17 feet by 3 feet 4 inches of useful depth. In each bed a small chamber is partitioned off at the outlet side of the bed by three masonry walls, in which an Adams' Automatic Timed Siphon is placed. The over-draw arm of the siphon goes through one of the partition walls and dips into the liquid contents of the bed, the inlet to the arm being protected by a perforated half-round galvanized iron sheet. A small bent pipe is placed at the side of the siphon, one end dipping into the small chamber, and the other into the liquid contents of the bed. When the latter is full, the pipe begins to lead the effluent from the bed into the small chamber, the rate of flow being regulated by a stop-tap fixed on the pipe in the chamber. When the chamber is filled to a certain height, the siphonic action comes into play, discharging the whole of the contents of No. 1 bed into No. 2. The duration of contact thus depends on the

time the chamber takes to be filled to the requisite height, which is, as stated above, regulated by the stop-tap. The same procedure then takes place in the No. 2 bed as in No. 1, the final discharge from it being into an open channel communicating with the main channel, which empties itself into two of the wells on the sewage farm. The filtering medium used in both the beds is coal clinker, that in No. 1 being broken to pass through a screen with 1 inch meshes, and that in No. 2 through one with $\frac{3}{4}$ inch meshes.

The following is the cycle at present in vogue for the filling and the emptying of the Contact beds during 24 hours. No. 1 Contact bed commences its contact at 9 a.m. each morning, and remains so until 11 a.m., when it automatically discharges into No. 2 bed, a proceeding which takes exactly 30 minutes. No. 2 bed is then in contact until 1-30 p. m., and is finally emptied by 2 p. m. Both beds then remain empty until 5 p.m., when No. 1 fills again and is in contact until 7 p.m. It then automatically discharges into No. 2 bed, and the same procedure as in the morning takes place, No. 2 bed being finally emptied at 10 p.m., after which both the beds remain empty until 9 a.m. the next morning, so that in the 24 hours each bed rests empty for $5\frac{1}{2}$ hours after the first contact, and $13\frac{1}{2}$ hours after the second contact.

There is no doubt that the contact can be made much shorter when the beds are thoroughly in working order and experiments will be undertaken to ascertain the shortest effective contact.

The Contact beds commenced working with the Septic effluent on the 15th of September 1902. From that date until the end of the month, they received one filling a day. From 1st of October and onwards they received two fillings a day as described above.

On the 13th and 14th of October, Dr. Cayley made the following analyses. A sample of crude sewage entering the Septic Tank at 8 a.m. on 13th October, was taken by removing a certain quantity of sewage every 10 minutes until a bucket was filled. The sewage was then stirred and mixed, and a bottle removed for analysis. Dr. Cayley describes the sample as "thick, dirty yellow; considerable quantity of fœcal sediment; offensive smell."

	Crude Sewage.	Effluent from Septic Tank.	Effluent from No. 1 Contact Bed.	Effluent from No. 2 Contact Bed.	
Free Ammonia ...	11·300	9·408	4·704	2·640	Parts per million.
Alb. Ammonia ...	26·450	2·520	1·740	1·180	
Total Solids ...	102·00	23·00	16·00	15·00	Grains per Gallon.
Suspended Solids ...	53·00	3·00	......	......	
Chlorine	3·6	2·4	2·1	2·05	
Nitrites as NO_2 ...	......	......	......	0·115	Parts per 100,000
Nitrates					
as N	......	......	......	0·5	
as NO_3	......	......	......	2·214	

During the fortnight succeeding the 15th of October, a very striking improvement was noticed in the effluents from both the Contact beds. This was undoubtedly due to the fact that the beds were getting into good working order and also to the increase in the temperature of the sewage. An estimation of oxygen absorbed in 4 hours, made by Dr. D. A. Turkhad, M.B., C.M., (Edin.) on the 18th October, of the effluent of the 2nd Contact bed gave a result of 1·35 of absorbed oxygen in parts per 100,000. A

similar estimation made on the 25th October, also by Dr. D. A. Turkhad, gave a result of 0·42, showing a large increase of purification in the week's working. On the 26th of October an estimation, made by Mr. G. Midgley Taylor, M.I.C.E., F.C.S., of the effluent of the same Contact bed gave 0·28 of oxygen absorbed in 4 hours in parts per 100,000.

These figures shew that after only 6 weeks' working a result is obtained equal to any in Europe even after passing through a series of three contacts.

A branch pipe, one inch in diameter, is taken off from the 2-inch pipe to the Contact beds to supply a "Streaming filter." The sides of this filter are constructed of dry brick supported at four places by dry rubble stone buttresses. The filter is 12 feet in diameter by 7 feet in height. The filtering medium is again coal clinker, but of uneven size from 2 to 3 inches. The Septic Effluent is distributed on to the filter by one of the Adam's patent "Rotating Distributors." This distributor consists of a bucket rotating on ball bearings fitted with radial arms of ¾ inch galvanized pipes, perforated with holes every 5 inches. These holes are made only on one side of the pipe and in opposite directions to one another, the pressure of the water on the sides opposite to the holes forcing the arms to revolve. The apparatus can be worked with two or more arms according to the flow of sewage.

The radial arms depend for their velocity upon the head of liquid and angle of delivery; by depressing the arms the number of revolutions can be increased.

If it is desired to sluice the filter out, the arms should be depressed and the flow of sewage increased to such an extent, that in a short time the filter is cleansed of its solid matter. This is a very satisfactory way of cleansing the filter and is obviously more economical than removing all the material and washing it.

The amount of material remaining in the filter is however small, as filters worked on this principle eject a certain amount of the solid matters along with the effluent. The solid matters thus ejected are quite innocuous and readily settle, leaving the liquid effluent brilliant and clear.

The Septic effluent takes about 15 minutes to pass through the filter. The radial arms thoroughly distribute it over the surface of the filter, and the discharge at the bottom is equal at all points.

The following are the three analyses made by Dr. Cayley of the Crude Sewage, Septic Effluent, and the effluent from the Streaming Filter, the latter being after the Streaming Filter had been in work for a fortnight. This Dr. Cayley describes as having a slight milky appearance, faint brownish tinge, trace of sediment, and slight earthy smell :—

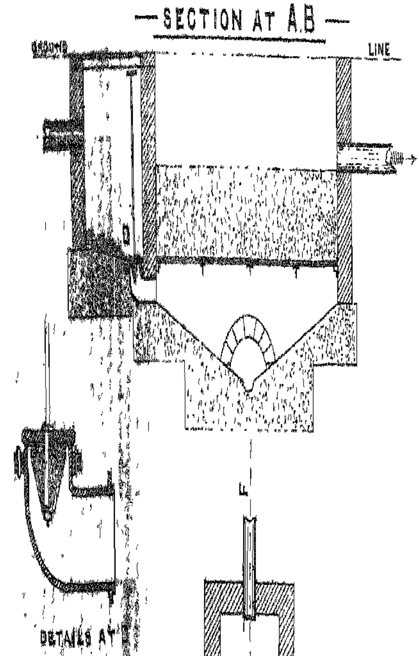
	Crude Sewage.	Effluent from Septic Tank.	Streaming Filter.	
Free Ammonia ...	11·300	9·408	3·040	Parts per million.
Alb. Ammonia ...	26·450	2·520	1·480	,,
Total Solids	102·00	23·00	18·00	Grains per gallon.
Suspended Solids ...	53·00	3·00	......	,,
Chlorine	3·6	2·4	2·1	,,
Nitrites as NO_2 ...	......	......	1·314	Parts per 100,000
Nitrates—				
as N	......	......	0·35	
as NO_3	......	......	1·55	

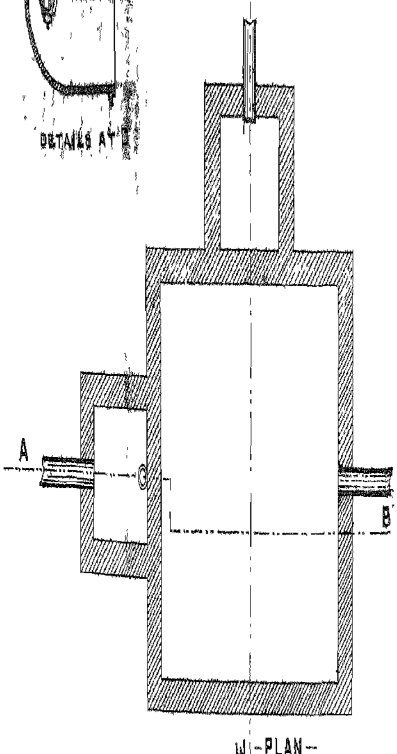
MACERATING TANK

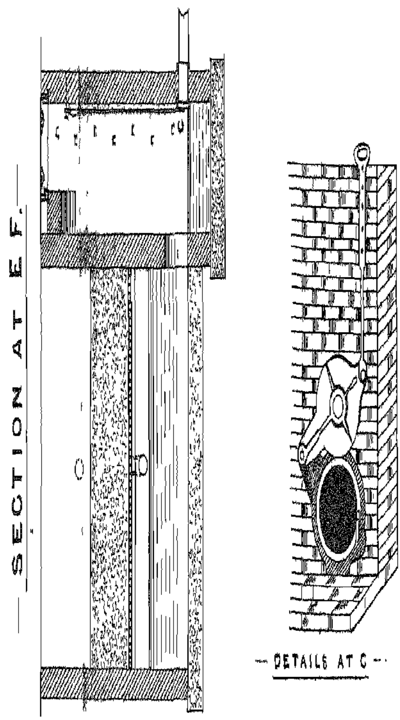
AT

A BULK OIL INSTALLATION

SCALE 4 TO 1 INCH







This éffluent, although the Streaming Filter has been working for only 15 days, is nearly as good as the result obtained from the double contact.

That the effluent has improved since the analysis made by Dr. Cayley, there is no doubt. It is much clearer in appearance, and an estimation made by Mr. G. Midgley Taylor, M.I.C.E., F.C.S., of the oxygen absorbed in 4 hours, on the 26th October, 12 days after the analysis made by Dr. Cayley, shews it to be a first class effluent. A sample of the Septic effluent taken from the radial arms, and 15 minutes afterwards a sample of the effluent from the filter, gave the following results :—

	Parts per 100,000.	
Septic Tank effluent...........	0·59	Oxygen absorbed in 4 hours.
Streaming Filter effluent.....	0·07	,, ,, ,,

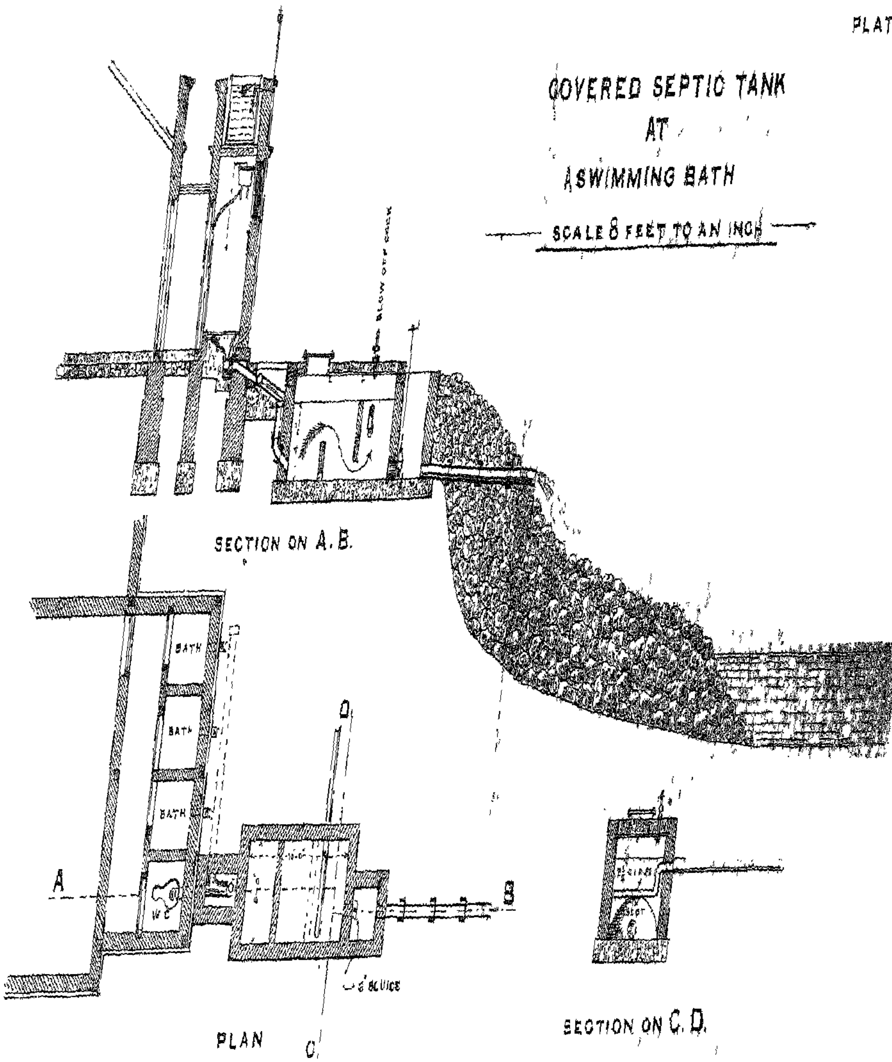
Taking into consideration the fact that the streaming filter has been in use for only about a month, the above results cannot be considered otherwise than exceedingly satisfactory. The filter is very simple in construction and the rotating distributors work easily under a head of one foot six inches. Beyond the fact that the ball bearings require to be lubricated and the orifices in the arms to be occasionally cleansed, the apparatus needs no particular supervision, and undoubtedly this class of filter has a great future before it.

Plate 47 shews a drawing of a Scott-Moncrieff Upward Filtration Bed or Macerating Tank, 9 feet by 9 feet by 3 feet deep, constructed to deal with the drainage from the sanitary conveniences, belonging to a Bulk Oil Installation in Bombay, which, owing to adverse levels, could not be connected with the sewerage system of the city. The effluent is discharged direct into the harbour. The tank

was constructed in June 1900, and has since been working continuously without creating any nuisance. It deals with all the sewage from the Manager's quarters and from a series of latrines, built to accommodate 100 workmen engaged on the premises. The filtering material is 2 feet in depth and consists of burnt brick, graded from 1 inch cube at the bottom to $\frac{3}{4}$ inch at the top, whereon is finally spread a layer of 2 inches of fine sand. A sluice is provided to flush out the sludge when necessary, an arched opening in the bottom of the tank communicating with the sluice chamber for this purpose. As before stated, the effluent is discharged into the harbour, where it is immediately mixed with a large volume of sea water. It is almost entirely deprived of the solids in suspension in passing through the tank, and under the special conditions of its discharge, no further purification has been necessary. The installation is economical, but it could only be effective with comparatively small quantities of sewage and under conditions where an immediate large dilution of the effluent takes place.

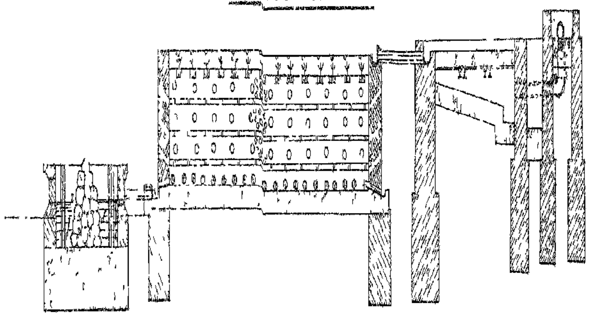
Plate 48 shews a drawing of a Septic Tank constructed in connection with the lavatory of a Swimming Bath on the seashore at Bombay, containing one water closet, one urinal and three shower baths. The effluent from the tank is discharged into the sea. In this instance the tank is covered principally for sentimental reasons. It measures 10 feet by 5 feet by 4 feet deep and is designed to receive sullage from 150 persons, that being the largest number likely to visit the bath in any one day. The amount of the fœcal matter is small, but that of urine is proportionately large. The tank is divided into three compartments, a dwarf wall 2 feet high separating the first and the second

PLATE 48

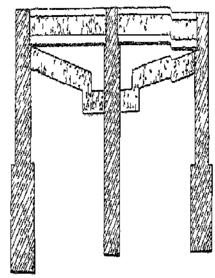


COVERED SEPTIC TANK
AT
A SWIMMING BATH
SCALE 8 FEET TO AN INCH
BLOW OFF COCK
SECTION ON A. B.
BATH
BATH
BATH
W C
A
B
C
D
SLUICE
PLAN
SECTION ON C. D.

— SECTION ON A B —

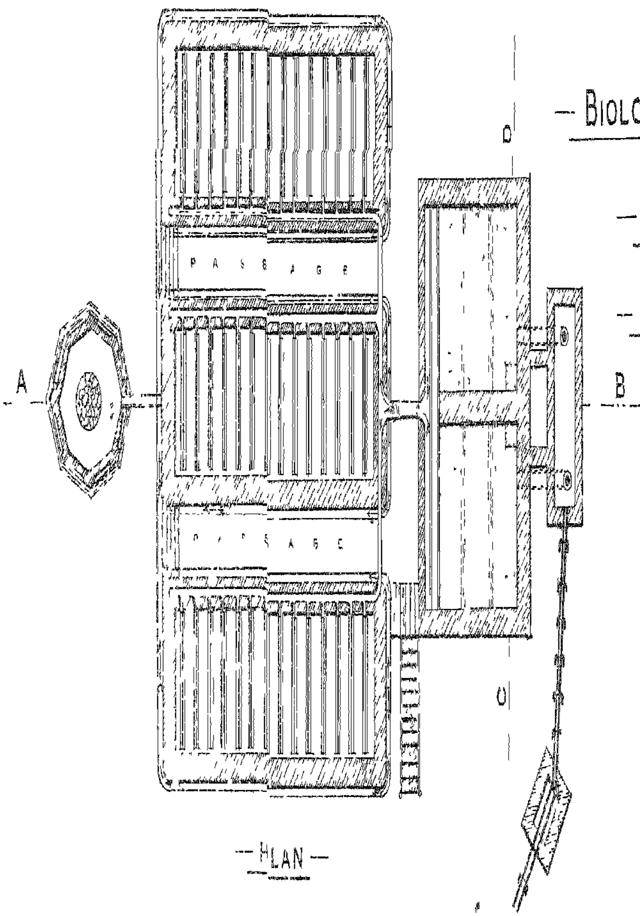


— SECTION ON C D —



— BIOLOGICAL INSTALLATION —
— AT —
— A SANATORIUM —

— SCALE 10 TO 1 INCH —



— PLAN —

compartments, the object of the wall being to break the velocity of the sewage on entering the tank. An arch two feet in depth from the top is thrown between the second and the third compartments. These two barriers effectually break the velocity of the sewage and at the same time leave the scum on the surface undisturbed. A 4-inch pipe with $\frac{1}{2}$ inch slots is placed in the third compartment through which the effluent discharges. A sluice is provided at the bottom of the tank to clear it of sludge when necessary, and a blow-off cock at the top of the covering of the tank for the escape of the gas. Unfortunately very little night-soil finds its way into the tank, but the purification of whatever goes is sufficient to permit of the discharge of the effluent on to the foreshore without creating any nuisance, it being clear and comparatively free from smell.

Recently it became necessary to make arrangements for the drainage of a large Sanitarium in an unsewered district in Bombay and the arrangement shown in Plate 49 was carried out. This installation provides for all the sewage of the establishment being brought to a point and discharged into two Macerating Tanks, each 10 feet square and 4 feet deep. The tanks are placed side by side, so that they can be worked together or alternately, one being in use, while the other is being cleaned, or kept in reserve. The lowest point of each Macerating Tank is connected by means of a sluice and a 9-inch pipe to a sludge tank for cleaning purposes. The sewage from the Sanitarium flows in at the bottom of the Macerating Tank and filters upwards through 14 inches of road metal, the level of which is raised slightly higher than the weir connection with the open drain, which leads to the filters, thus avoid-

ing room for the growth of mosquitoes in the standing sewage. The filters are three in number and are constructed in a similar manner to Col. Ducat's Absaf Filter. Each of them is 25 feet by 8 feet by 6 feet in depth. The sides are of concrete, honey-combed with 3-inch stoneware pipes, spaced about 3 inches apart. The outer ends of these pipes are at a higher level than the inner, the slope being to guard against the fluid passing out from the sides of the filter. Longitudinal and lateral pipes with open joints run right through the filter for the promotion of aeration, and these are spaced about 2 feet 4 inches apart horizontally, and 1 foot 5 inches vertically.

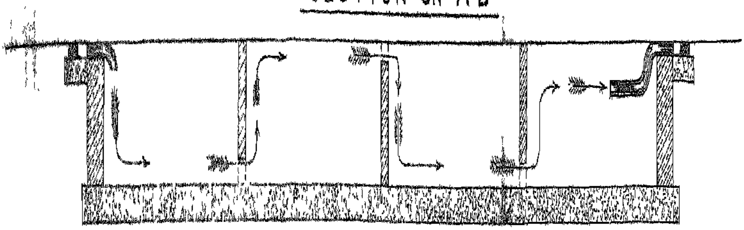
The filtering material is entirely clinker, varying from ¾ inch at the top to ½ inch at the bottom. The sewage is discharged on to tipping troughs from open channels running at right angle to them. The troughs are of the same kind as those described for the Ducat's Filters at Matunga and are fixed 1 foot 9 inches apart from centre to centre, each trough running the full width of the filter; the sides of each trough are 3 inches apart at the top.

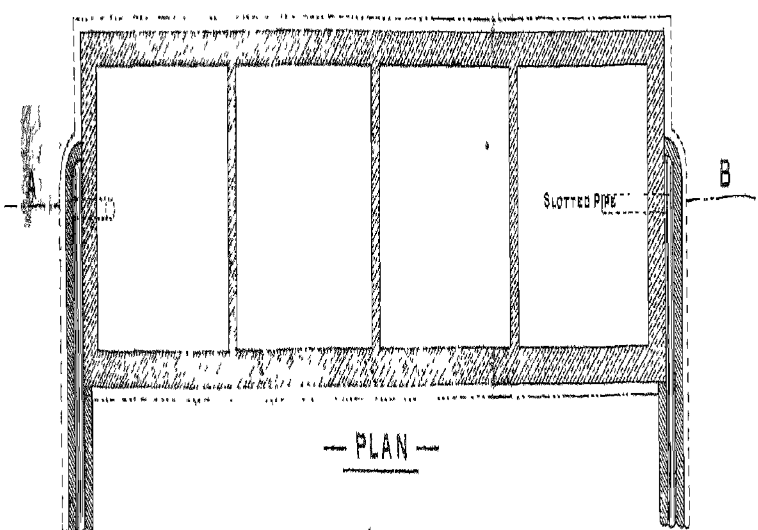
The installation is designed to completely dispose of the solid and fluid matter from 36 water-closets, the sullage from 50 nahanis, and all the waste water from the cook-rooms. The effluent from the filters discharges into an ornamental tank surrounded by ferns, in which gold fish would thrive, and the effluent can be used without any offence for gardening purposes. The maximum population is 200 people.

This installation is in a residential part of the town, and the Sanitarium is now nearly fully occupied and there is no nuisance of any kind from the sewage disposal works.

A TYPICAL SEPTIC TANK

SECTION ON AB





PLAN

SCALE OF 4' FEET TO AN INCH

The following analyses of the crude sewage and of the effluent made by Dr. Cayley show how exceedingly satisfactory the purification is :—

	Crude Sewage.	Effluent.	
Free Ammonia	17·32	0·2	Parts per million.
Alb. Ammonia.......	5·44	0·28	Do.
Chlorine	3·2	4·9	Grains per gallon.
Total solids..........	59	47·0	Do.
Dissolved solids.....	36	......	Do.
Suspended solids...	23	......	Do.
Nitrites................	Nil	·126	Parts 100,000.
Nitrates...............	Nil	4·5	Do.

"A very good effluent. Most of the organic matter "has been converted into nitrates."

The effluent for this analysis was taken 35 minutes after the crude sewage, but it is evident that the effluent is one of a stronger sewage. The result is eminently satisfactory and with the experience gained at Matunga there is no reason to suppose that the installation will not always continue to give good results.

Plate 50 shews a useful drawing of a small open Septic Tank, 25 feet by 6 feet by 3 feet, to hold 2,800 gallons of sewage, designed for a hospital. It will be noticed that the tank is divided by three baffle walls, the use of which is to break the velocity of the sewage going

through the tank; these walls need not be more than $4\frac{1}{2}$ inches thick. The sewage alternately passes over and under them and finally discharges through a slotted pipe. A 6-inch sluice should be fixed at the discharge end of the tank for cleaning purposes. A Septic Tank built on these lines will be found to be quite successful.

One of the worst forms of sewage that the Sanitary Engineer has to deal with and one that is often met with in India is undoubtedly that from tanneries. It is usually composed of spent lime and other chemicals, highly charged with organic matters, both of animal and vegetable origin. Sewage of such composition, as this, cannot be treated biologically and it can only be satisfactorily dealt with either by chemical treatment, or by passing it through precipitating tanks, after first cleaning out floating matter such as hair, etc., and afterwards largely diluting it with fresh water and discharging it either into the sea or a river. The usual method of treating tannery sewage in England is to add Sulphate of Alumina, which can be cheaply purchased under the trade name of Alumino-ferric.

The chemical effect of the addition of alumino-ferric to tannery sewage, which is strongly alkaline owing to the lime used in the tanning process, is to produce a dense precipitate, which in settling carries down solid matters and also certain portions of dissolved organic matter and at the same time removing a large proportion of the colour from the effluent. The effluent, however, from the tank is, even after being chemically treated, of a foul and offensive nature. All tannery sewage, before entering the precipitating tank, should be efficiently screened through screens with spaces not more than $\frac{1}{2}$ inch wide. The bars of these screens should be rectangular in shape, the screens them-

selves sloping at an angle of 45°, a hand rail being provided at the top to enable the raking of the screens to be easily and safely effected. A scum board should also be placed across the tank to catch any floating substances that evade the screen. All screenings and surface floating matter removed from the tanks should be burnt. The solid matters retained in the precipitation tanks will require to be removed from time to time and the best means of doing this is by employing a chain pump.

It is desirable in case of all tanneries, that arrangements should be made to compel each owner to treat the sewage of his own tannery, before it leaves the premises.

CHAPTER VI.

Surface Water and Sub-soil Drainage:—Assuming that a Separate System of Drainage has been decided on, the question of disposing of the Surface and Sub-soil Water of each district then calls for consideration.

The amount of rain which falls in a district is, in most centres, officially observed and recorded, and there are few places now where that information cannot readily be obtained for a series of years sufficient to enable a just average to be determined.

In a Separate System of Drainage, the capacity of the sewers must provide for that amount of rain which falls on such roofs and on such open paved surfaces enclosed by houses as cannot drain to the surface water drain in the street without a special connection. The reason for this is that it is very undesirable to have both a sewage and a surface water drain within house-premises, as there would then be the risk of unsanctioned sullage connections being made to the surface water drains, which would generally be more convenient from the householders' point of view.

Wide fluctuations of rainfall occur at different places, even in one district, and as a rule the rainfall increases with the elevation. A Meteorological Observatory, such

as exists in Bombay, is of the greatest assistance to the Engineer, as valuable data extending over many years can generally be obtained therefrom.

In designing a scheme of surface water drainage, the rainfall, the configuration of the land, and the area paved and built upon are the chief considerations.

In the case of towns on the sea coast, the waters from high-lands should be separated from those of the low-lands. "High-lands" include lands at or above the level of the high-water mark of ordinary spring tides, and "Low-lands" those below that level.

The waters from high-lands should be taken by drains discharging directly into the sea by the nearest route, the *outlets being protected by means of tidal flaps.* Those from low-lands will have to be stored during the time of high water and discharged into the sea through sluices at the ebb tide.

In the case of high-level drains discharging continuously and directly into the sea or a river without provision for storage, the maximum hourly rainfall is the chief factor in determining the size of such drains. Tables should be prepared from meteorological data to ascertain how many times a year the hourly rainfall exceeds certain quantities, and from such tables the maximum hourly rainfall to be provided for can be easily ascertained.

As an example, the following table, showing the number of times the hourly rainfall exceeded the given amounts in ten years (1886-1895) in Bombay, will be found interesting. It will be seen that there were on an average only 5·3 hours in a year when the hourly rainfall exceeded

1 inch. Therefore, in Bombay, all high-level drains may be designed to carry 1 inch of rainfall per hour.

Year.	Under $\frac{1}{4}''$ per hour.	$\frac{1}{4}''$ to $\frac{1}{2}''$ per hour.	Above $\frac{1}{2}''$ to $\frac{3}{4}''$ per hour.	Above $\frac{3}{4}''$ to 1″ per hour.	Above 1″ to $1\frac{1}{2}''$ per hour.	Above $1\frac{1}{2}''$ to 2″ per hour.	Above 2″ to $2\frac{1}{2}''$ per hour.	Above $2\frac{1}{2}''$ to 3″ per hour.
1886	497	31	17	8	5	4	2	1
1887	654	46	14	4	2	7	1	0
1888	479	39	9	4	0	1	0	1
1889	562	37	12	4	1	0	0	0
1890	620	46	10	0	3	0	0	0
1891	469	49	8	7	6	2	0	0
1892	622	71	20	11	4	1	0	0
1893	476	45	7	4	1	0	0	0
1894	597	46	6	0	2	0	0	0
1895	534	56	7	4	9	0	0	0
Averages ...	551·0	46·7	11·0	4·6	3·3	1·5	0·3	0·2

In the case of low-lands, the method for determining the size of the drain, etc., is different. It should be ascertained how many hours per tide, on an average, storage will be required, and the amount of the maximum rainfall for that number of hours consecutively should be obtained from the meteorological data, and storage, drains, etc., calculated for and provided accordingly.

Consideration must also be given to the amount of the rainfall that will flow off the surface of the ground. In

fully built-upon areas, such as will be found in the centres of towns, it will be necessary to allow for all the rainfall to flow off, for the percentage that will soak into the ground is not an appreciable amount and need not be considered.

In suburban districts with gardens, etc., 65 to 75 per cent. of the rainfall must be provided for in a surface water scheme, but in rural and sparsely populated districts only 10 to 20 per cent. need be taken into consideration. No definite rule can be laid down for the amount that will flow off in rural districts, the nature of the soil naturally having much to do with that amount.

One inch of rainfall in depth over one acre per hour is equal to 3,630 cubic feet, or 22,687 gallons, per hour, or just one cubic foot per second. Consequently, drains designed for an hourly rainfall of 1 inch should be capable of discharging as many cubic feet per second as there are acres to drain.

In India, where the rainfall is usually confined to a specific season of the year, heavy daily falls are not uncommon, but they are usually not of long duration, and such flooding, as will temporarily occur, soon disappears and is more or less immaterial. In districts where the rainfall is small, the storm-water is generally loaded with impurities, particularly at the time of the first flood, analyses showing the liquid to be almost as impure as sewage; subsequent flows may, however, be comparatively pure.

The considerations, which govern the directions of sewers in a sewerage scheme, will be even more applicable to the drains in a surface water scheme, that is to say, they should always, if possible, follow the natural drainage of the district, and in this way nature provides the

outfalls at which the surface water will discharge. The number of outfalls is not restricted as in a sewerage scheme and this tends considerably to economy.

The calculation for the size of surface water drains is not difficult, the Engineer having decided on the amount of the maximum rainfall per hour and on the percentage of rainfall which will flow off the district to be drained. All the water from such of the roofs of the buildings, as are not drained into the sewers, is led by eave gutters and cast-iron pipes into a house gully or discharged on to the roadside water tables or into the roadside drains, the water thence flowing to the nearest water-gully connected with an underground drain. The system of surface water drains will naturally commence with open roadside drains or water tables, the former being constructed of sizes determined by the area and the rainfall to be disposed of.

Fig. 34 shows a roadside drain, 12 inches × 18 inches deep. The wall on the roadside is built of rubble

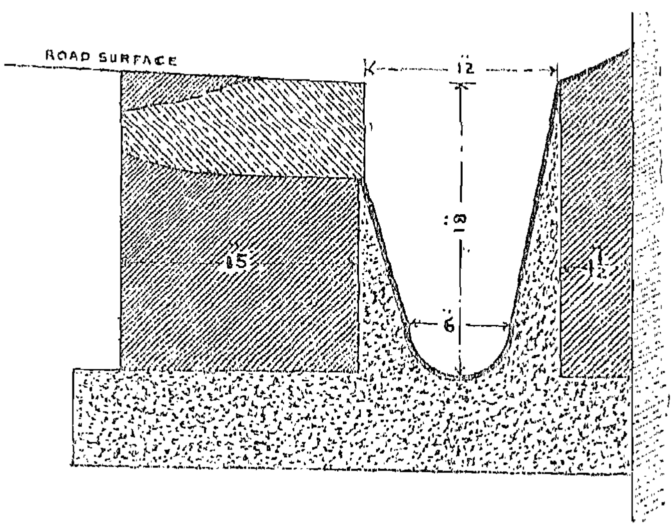
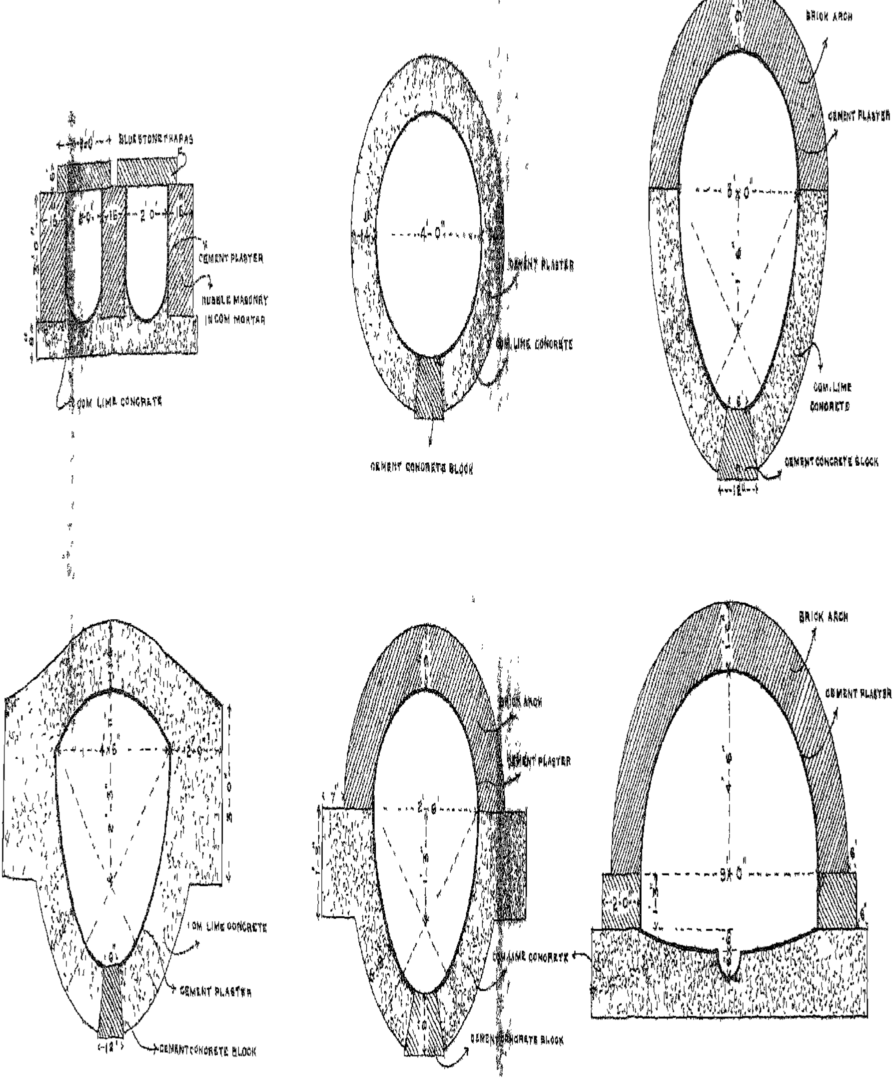


FIG.

PLATE 51

DIFFERENT DESIGNS FOR STORM WATER DRAINS



masonry in common mortar, 15 inches in thickness, while the inner wall is constructed of $4\frac{1}{2}$ inch brickwork, resting against a compound wall or plinth of a house. The foundation is formed of lime concrete, and the invert of a 4-inch or a 6-inch channel pipe. The haunches are filled up with cement concrete and the whole of the interior rendered with cement plastering. The roadside wall is built within 6 inches of the ground surface and is finished off with stone khankis or kerbing, 12 inches in width, 15 inches in tail and 6 inches in thickness.

The next transition is to underground pipe drains of stoneware or cast-iron from 6 inches to 18 inches in diameter, the next being to underground masonry drains, covered with stone slabs, 6 inches in thickness, as shown in Fig. 35, which gives a section of a drain 2 feet by 2 feet in area. The foundation is laid in lime or cement concrete, 9 inches in depth, the former being used in dry, and the latter in wet ground. The walls are built of rubble masonry in lime mortar 15 inches in thickness, and the half-round invert formed of cement concrete, the whole of the inside being rendered with cement and sand (1 to 1), ½ inch thick.

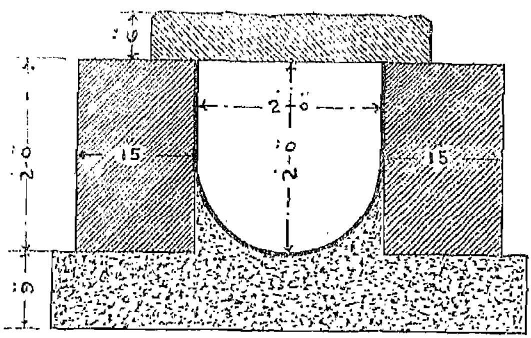


FIG. 35.

The sizes of the drains will increase in accordance with the quantity of the water to be discharged and various sizes of such drains are shown in Plate 51.

To ensure efficient drainage, all roads and streets should be constructed with a camber of not less than 1 in 40, as shown in Fig. 36, and the sides finished with a line of slab stones, 15 inches by 12 inches by 4 inches thick, set in lime concrete, and generally known as water tables, on which the surface water will naturally flow. These water tables should grade each way at a slope of

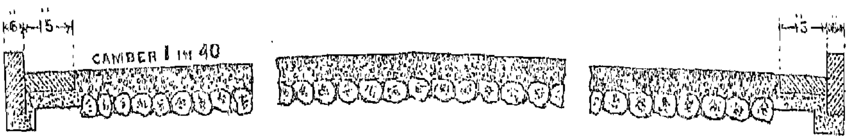
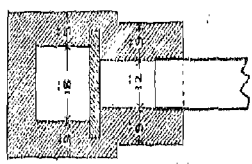


FIG. 36.

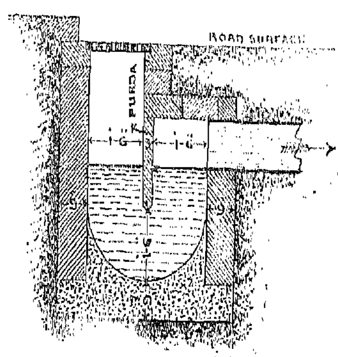
not less than 1 in 200 to a sealed chamber or water-gully connected with the underground surface water drain in the road.

Fig. 37 shows a very satisfactory type of surface water gully. It will be noticed that the trap or seal of the water gully is 9 inches. The bed of the chamber is constructed of a 9-inch layer of common lime concrete, the invert being formed of cement concrete. The walls are constructed of brickwork in common mortar, the whole of the inside being rendered with cement and sand (1 to 1), ½ inch thick. The parda or diaphragm is of blue cut-

WATER-GULLY.



PLAN.



SECTION

FIG. 37.

stone, smooth dressed and so fixed as to dip into the water to a depth of 9 inches, and dividing the chamber into two parts. The part of the chamber nearer the underground drain is covered with 6 inch stone slabs, while the other part is brought up to the road surface, and covered with a cast-iron grating, 20 inches by 20 inches, resting on a cut-stone rebated curb, 9 inches by 6 inches. The depth of the seal of surface water gullies in India should never be less than 9 inches on account of evaporation, which so rapidly takes place in this country.

In a large city, it is very difficult to keep surface water drains absolutely free of sewage and, unless constant supervision is exercised, house connections are made to them, especially if that drain is the most conveniently situated for the house owner, and this is a further reason for recommending the water seal to be so great. During the dry season it is a convenient plan to fill in all water gullies, right up to the grating, with clean sand ; this allows of the road watering soaking through and passing into the drain, but prevents foul air from coming out into the street. In a general way it is not necessary to arrange for the ventilation of surface water drains, as, even though the first flow of rainfall may be very foul, it is usually followed by a much clearer liquid and the deposit in the drain is usually nearly all mineral matter which will not decompose.

Fig. 38 shows a drawing of a manhole on a surface water drain. It has been found desirable to lower the floors of the manholes as shown in the figure. They then act as catch-pits, and facilitate the cleaning of the drain. The manhole is constructed of brickwork in lime mortar, 9 inches in thickness, the side walls resting on those

of the drains and the end walls on the 6 inch dhapas. The whole of the inside of the brickwork is rendered with

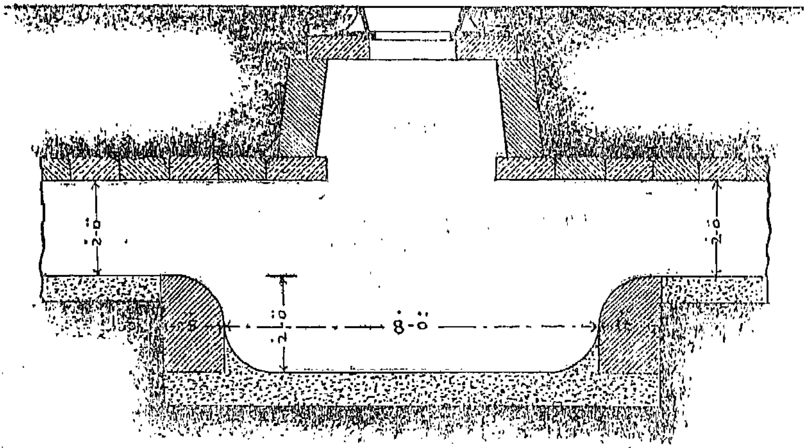


FIG. 38.

cement and sand (1 to 1), ½ inch thick. Cast-iron steps, as before described, are inserted in one of the walls to enable the workmen to descend into the manhole. The manholes are covered with the ordinary type of covers and frames, shown in Fig. 1 in Plate 8.

The cleaning of surface water drains is usually done by hand and during dry periods. It is not accompanied by any danger from polluted air, and therefore the rules which apply to sewer-cleaning need not all be enforced.

Sub-Soil Drainage.—The question of sub-soil drainage should always have consideration from the Sanitary Engineer as the level of sub-soil water has much to do with the health of the community. The principal source of moisture in soil is rain, but it may arise from other causes, such as springs or excessive water-supply and wastage of the same. It is only when the sub-soil water is

in excess and becomes stagnant and is close to the surface of the ground, that it becomes dangerous to health.

A saturated sub-soil prevents the circulation of fresh rain water through the soil, vegetation thereby losing the benefit. The effect of a wet or saturated soil is to reduce the temperature of the air, is very often the cause of fogs, and is always the cause of mists arising from the ground, which are naturally injurious to health. A sub-soil of wet clay will shrink in drying about one-fifth of its bulk and swell again when wet, and for that reason buildings on such sub-soil should always have their foundations taken down below the reach of atmospheric changes; this depth in clay may usually be taken as 5 feet. Clay is a soil which is very retentive of moisture, and one cubic foot in most dry clays will absorb about one gallon of water. To get rid of superfluous water, sub-soil drainage is often necessary on sanitary grounds. If the sub-soil is composed of sand or gravel or loamy earth, then any liquid reaching the ground passes away by percolation, but this is not so in clay, which will take up moisture and retain it until it can hold no more, and any further supply of liquid remains, or drains away on the surface if it can find an exit. A large proportion of the sub-soil in Bombay is clay overlying the balsaltic rock and certain low-lying parts of the Island are always wet, leading to much unhealthiness. The laying of drains and sewers generally has a beneficial effect in lowering the level of the sub-soil water, and provides a passage for it along the sides of the drain and the sewer. It is sometimes a good plan to put a layer of road metal around the drain or sewer for the sub-soil water to flow through.

The Author has sometimes found it useful to fix in the side walls of a surface water drain flap pipes to allow of sub-soil water finding its way in ; these pipes should not be placed below the springing line of an arched drain.

Sub-soil drains should not be less than 4 feet below ground level. Certain authorities recommend deeper drainage, and it is an undoubted fact that the deepest drains flow first and the longest. The filling in of old tanks is a question that crops up frequently in a large city like Bombay. Such tanks are often very deep and serve no useful purpose when a sufficient water-supply exists, but on the other hand they become the receptacle for all kind of rubbish and filth. Under these circumstances they should be filled in with good clean earth and kept as open spaces ; but as sub-soil water has always been flowing into the same according to the level of the water in them, in filling up such tanks a wall of coarse rubble or road metal, in which should be laid stoneware pipes with open joints, should be constructed all round the tanks, starting at a depth of 5 feet, that being about the depth at which sub-soil water ceases to be unhealthy, and the pipes graded to a point where a connection can be made with the nearest surface water drain.

Wells abound in all large cities and their water unfortunately, no matter though it be greatly contaminated, is preferred by many Hindus to the pipe supply. The watchful control of wells is an important Municipal duty, and Health Officers are frequently called upon to take action in regard to those that are a menace to public health.

The question of filling in wells is a fruitful source of friction between the public and the authorities, and no measure of equal sanitary importance is more keenly opposed. The

fouler the well and the more necessary its filling in in the interests of public health, the greater are generally the demands that it shall be spared, usually on religious grounds. Although the most sympathetic and respectful consideration should at all times be given to the genuine religious sentiments of the people, a limit is often reached in sanitary matters, beyond which it would be the falsest kindness to go. Many wells are found on analyses to be seriously contaminated by sewage, and to allow such to remain and spread disease, as they inevitably do, is nothing short of criminal.

CHAPTER VII.

Notes on the Drainage of Bombay:—This book would hardly be complete without a short history of the drainage of Bombay, for there is no city in India, and possibly in the East, where such strides have been made in sewerage and in sanitation generally. Many races of the world are represented there, each with its own distinctive domestic customs, and the conditions of drainage are therefore varied and uncommon.

The history of the drainage of Bombay is as interesting as it is exceptional, and if, in the light of later experience it has been found that mistakes have been made, it must be remembered that even so recently as twenty years ago sanitation was to a great extent empirical and the system of "trial and error" had inevitably to be largely resorted to. Devious although the approach may have been, there is little doubt that Bombay has now arrived at a satisfactory scheme, a study of which, with its great variety of circumstances, must prove of the highest instructive value.

Plate 52 is a copy of an old plan of Bombay, as it existed in the year 1672, when it consisted of seven separate islands. These have all now disappeared as such, owing partly to the action of nature, but mostly to the work of man; the red boundary in the Plate shows the island as it exists at the present time. It will be seen that a more difficult place could hardly be found for drainage purposes than this city, with its large area of reclaimed ground below high-water level.

The population of Bombay in the latter part of the seventeenth century is recorded as only 60,000, and the various islands are known to have been inhabited by people belonging mostly to the fisher caste and many traces of old fishing villages and the descendants of the people themselves still remain in parts of the city.

During the period from 1672 to 1845, in which year the Municipal interests of the city were entrusted to a Board of Conservancy, much was done towards reclaiming the spaces between the islands. There was, however, left for drainage purposes an open ditch, known as the old main drain, which ran from where the Crawford Market now stands, *via* Abdul Rehman Street, Paidhoni, Bapu Khote Street, and Falkland Road to the Flats, where it emptied itself into a tidal estuary. No attempts were made to arch over any portion of this drain until 1824, and it was not until 1845 that it was covered even as far as Paidhoni, though the progress after that was comparatively rapid, and by 1856 the arching had been completed upto Bellasis Road.

The size of this old main drain varied. At its commencement in Abdul Rehman Street it was 2 feet by 2 feet. After passing Paedhoni its size was much increased, no doubt because of cross drains running into it, it being at that point 10 feet 9 inches wide by 4 feet high with a gradient of 1 in 450. In Falkland Road its size was further increased to 20 feet 3 inches by 8 feet 6 inches with a gradient of about 1 in 5,000. In Bellasis Road, where it received the drainage of that part of the island even then known as Byculla, its size was 20 feet 3 inches by 9 feet 10 inches, with a gradient of about 1 in 1140. From this point it ran over the Flats to the sluices in an open cut. The arching consisted, for the most part, of roughly-dressed stone with side walls

of the same material. In many parts there was no foundation, but where any existed it was of rough rubble. This drain carried all the surface water in the monsoon and all the year round such sewage, as was discharged into it by gravitation or by hand. The state of sanitation must, indeed, at this time have been serious, considering the flat gradients and defective construction of the old main drain. It must have been a vast elongated cesspool, and probably always contained a large quantity of putrefying sewage. This old main drain exists even to this day, though much improved by having been repaired and in parts re-built. It is, perhaps, needless to add that it is now used for storm-water only.

Things had become very serious by 1853, when Mr. Conybeare, a "Superintendent of Repairs," submitted a plan to the Board of Conservancy for alleviating the nuisance resulting from the old main drain. His plan provided for no alteration to the condition of things during the monsoon, but during the dry weather it was proposed to run the sewage into a pit near Bellasis Road and to lift it after deodorization and use it for irrigation on the Flats. It is on record, and this is hardly surprising, that this did not improve, but rather intensified, the nuisance. Things continued much in the same way until 1860, when a scheme for the drainage of the city was submitted by Mr. Tracey, the Municipal Engineer, who seems to be the first Engineer, who seriously attempted to deal comprehensively with the whole of the drainage of the city. He objected to the application of sewage to land, and proposed its discharge by two outfalls into the harbour. In his proposals Mr. Tracey objected to an outfall on the west, as being the wind-ward side, and because he saw the risk of sewage deposit on the foreshore.

The scheme, briefly speaking, provided for the discharge of the sewage at two points, *viz.*, Wari Bundar and Carnac Bundar. It was proposed to discharge the sewage of Umerkhadi, Girgaum, Kamatipura, Tarwadi, and Nowroji Hill at the former outfall, and that of the Market, Mandvi, and Sonapur at the latter. At Carnac Bundar all the sewers were to discharge into the sea by gravitation only. At Wari Bundar there was to be a low-level as well as a gravitation system. The low-level sewers were to discharge into tanks, whence the sewage was to be pumped into the harbour at ebb-tide. The sewers on the gravitating system were designed to carry both sewage and storm-water, but from the low-level sewers, storm-water was excluded. The whole scheme was to cost Rs. 33,20,000.

Mr. Tracey's scheme was sent to England to the Secretary of State, and Mr. Robert Rawlinson, afterwards Sir Robert Rawlinson, K.C.B., was asked to report on it. Mr. Rawlinson reported favourably in 1863, with some slight modifications. It was accordingly sanctioned by Government in September 1863, and Mr. Tracey was appointed to carry it out, with Capt. Trevor as Consulting Engineer. But before much work could be done, Mr. Tracey unfortunately died, while Mr. Wilcox, his Assistant, who succeeded him, also died shortly after.

In the meantime an agitation was got up against the propriety of placing sewage outfalls so near the populated parts of the City, and Government appointed a Commission, of which Mr. T. Ormiston, the first Port Trust Engineer, was a member. Mr. Ormiston was of opinion that Colaba was the best point for the discharge of the sewage (a view that is now very generally accepted as correct), and

that storm-water and sewage ought to be separated, and Government concurring with these views condemned Mr. Tracey's proposed outfalls.

For a year or two no further steps were taken, and the next important epoch in the history of the drainage of Bombay was the scheme prepared in 1866 by Mr. Russel Aitkin, then Engineer to the Municipality, who proposed that the sewage should be discharged into a reservoir at Colaba near the Lighthouse and pumped into the sea on the ebb-tide. Mr. Aitkin objected to a "separate system" as impracticable in Bombay, and therefore provided for the sewage and the storm-water to flow away by the same drains. He proposed a main sewer from Null Bazar to Colaba with large branch sewers from different districts. These intercepting sewers were designed to carry a maximum rainfall of eight inches per diem in addition to the ordinary sewage of the districts to be drained. During the fair season, the sewage was to flow by the main sewer to Colaba where it was to be pumped into the sea. During the monsoon, the branch sewers were to be cut off from the main sewer, and to discharge the sewage and storm-water into the harbour or Back-bay, the flow being against the gradients. The main sewer from Null Bazar to Colaba was thus during the rains to carry off the sewage and storm-water, only from the low-lying district lying between Khetwadi and Bellasis Road. This main sewer was designed to carry off only two inches of rainfall per diem from this low-lying district, and Mr. Aitkin therefore proposed to retain the existing open main drain to receive the surplus, when more than two inches of rain fell in a day.

The whole cost of Mr. Aitkin's scheme was 110 lakhs of rupees, the annual working expenses being Rs. 2,50,000.

Mr. Russel Aitkin's views at that time regarding the velocity in the sewers strike one as curious in these days of advanced knowledge. In the main sewer the velocity was to be not more than 2½ feet per second, when running full with sewage and storm-water, but during the dry weather, it was to be only 1 foot or even 9 inches per second, and this was then supposed to be sufficient to prevent deposit in the sewers.

In 1867 Mr. Aitkin's scheme was forwarded to Mr. Robert Rawlinson, who was of opinion that sewage discharged at Colaba would return to the harbour. The natural fall of the Island towards the Flats and Worli indicated to him the true direction for the conveyance of the sewage. He further added that float experiments carried out by one Mr. Jagannath Sadashiv proved that a Colaba outfall would contaminate the harbour.

As regards these float experiments, which were believed in and relied upon for so many years as conclusive evidence that to discharge the sewage at Colaba would be fatal to the interests of the city, it is interesting to note that it was left to Mr. Baldwin Latham during his visit to Bombay in 1890 to discover that the arrows indicating the directions of the floats were wrongly shewn on the plan. That is to say, they pointed to the north instead of to the south and thus erroneously led to the conclusion that the current during the ebb-tide set into the harbour instead of flowing to the open sea. This extraordinary mistake has no doubt been the principal cause of Bombay having its outfall on its western foreshore with all the nuisance that has arisen therefrom.

Mr. Russel Aitkin's scheme, therefore, remained in abeyance, though some works proceeded in the Fort, which had its separate outfall near the Mint.

Pending the settlement of the main question of the drainage of Bombay, Mr. Aitkin also constructed a low-level sewer from Bellasis Road to Love Grove, which during the fair season intercepted all the sewage from the old main drain, and conveyed it to a Pumping Station at Love Grove, where it was lifted by one chain and two centrifugal pumps into the sea. The drainage of Kamatipura was also taken in hand, and brick-sewers and pipe-sewers were substituted for open drains. These sewers, though highly commended then, were afterwards condemned by Mr. Baldwin Latham in 1890.

In 1868 Captain, now Major, Tulloch came to Bombay from England, and the Municipality referred the drainage question to him. In November 1868 he submitted his report and advocated the segregation of sewage from storm-water and was of opinion that whether the sewage was applied to land, or discharged into the sea, it should be taken towards the west of the city, and not towards the harbour or Colaba. His reasons were that the natural slope of the Island was towards the west, and any discharge towards the east might foul the harbour.

He proposed to pump the sewage at Love Grove and to utilise it on land, or, as an alternative, to carry it back from Love Grove and discharge it at Colaba, if an outfall at that point were approved, though he was personally opposed to this. He was equally opposed to an outfall on the west, but ultimately his own reasoning in meeting the arguments of the opponents to his scheme led him inevitably to that point.

In 1869 Government appointed a Commission, with Mr. A. R. Scoble as President, to consider and report on the drainage and water-supply of Bombay, including a report on Major Tulloch's scheme.

The Commission concurred with Major Tulloch as regards the necessity for a "separate system," but they differed from him on several points, principally the carrying of the night-soil through the sewers, and the utilisation of sewage on land.

Plate 53 shews an interesting geological map of the Island of Bombay, prepared by Major Tulloch in support of his proposals to carry the main sewer towards Love Grove, that course running for the most part through made ground.

The report of the Commission, and the financial difficulties in which the Corporation found itself at the time, postponed any serious advance being made with the drainage until 1877, though during the interval some work was done, slowly and casually, as particular nuisances required to be dealt with.

The extension of building operations, however, aggravated the nuisances and in 1877 they became so intolerable that on the recommendation of the Town Council, the Corporation asked Government to appoint a Commission to advise as to what scheme was the best to adopt for the drainage of the city and Government responded by appointing four gentlemen with Surgeon General Hunter as the President. A number of witnesses were examined by the Commission, which issued its report in January 1878, recommending the adoption of Major Tulloch's scheme, as slightly modified by Mr. Rienzi Walton, the then Executive Engineer to the Municipality, who advocated the pumping of the sewage into the sea at the Love Grove outfall. This scheme consisted of laying a main ovoid sewer from Carnac Bundar to the Crawford Market, to be

continued along Sheik Memon Street, Bhuleshwar, Khetwadi, and the Flats to Love Grove, with a branch sewer from the Town Hall to the Crawford Market and another up Clerk Road. A Pumping Station was to be erected at Love Grove to pump the sewage into the sea. The Commission was further of opinion that house-connections would be suitable and that, provided the water-supply was not less than 20 gallons per head per diem, the night-soil might be freely admitted into the sewers, with a recommendation for the enforcement of a standard water-closet, except for huts and inferior buildings where house-connections were impossible. It strongly recommended free ventilation of all sewers, and the separation of storm-water from sewage.

The drainage of Bombay, as now carried out, has in the main closely followed these recommendations.

The report of General Hunter's Commission was an important one, as it marks the commencement of an entirely new era regarding the drainage history of Bombay.

The Corporation took the matter up seriously and in March 1878 sanctioned the scheme. The Government of India were asked to give a loan of Rs. 60 lakhs, most of which was to be devoted to its execution. The loan was refused and in September 1878 the Municipality itself raised a loan of 27 lakhs in Bombay, and in December of the same year the work was commenced under the supervision of Mr. Rienzi Walton, the Executive Engineer, who was placed on special duty for this purpose. The works immediately taken in hand were the main sewer from Carnac Bandar to Love Grove, certain branch pipe sewers, a Pumping Station with new plant at Love Grove and a new outfall sewer.

In May 1881 the main sewer, as it now exists from Carnac Bandar to Love Grove, was completed. It is ovoid in shape and of the following sizes :—

From	To	Sizes.	Distance in Miles.
Frere Road (Carnac Bandar).	South end of Sheik Memon Street.	2′-6″ × 3′-9″	0·52
South end of Sheik Memon Street.	Cawasji Patel Street.	2′-8″ × 4′-0″	0·78
Cawasji Patel Street.	Junction of Khetwadi Back Road and Khetwadi 10th Lane.	3′-4″ × 5′-0″	0·51
Junction of Khetwadi Back Road and Khetwadi 10th Lane.	Junction of Grant Road and Falkland Road.	3′-10″ × 5′-9″	0·14
Junction of Grant Road and Falkland Road.	Clerk Road Crossing.	4′-8′ × 7′-0″	0·35
Clerk Road Crossing.	Love Grove ...	5′-4″ × 8′-0″	0·95
		Total ...	4·25

The cost of the whole of this work amounted to 5 lakhs of Rupees.

By 1880, the outfall sewer from the Pumping Station to an out-let chamber on the foreshore had been completed at a cost of 2½ lakhs. This is a double barrelled masonry

sewer, each barrel being 3 feet 6 inches in diameter. From the chamber are laid two parallel 36-inch pipes, running into the sea 6 feet below low water spring tides. These pipes were not laid until the end of 1881.

Meanwhile branch pipe sewers had also been laid, connecting with the main sewers, in various streets, at a cost of 2½ lakhs.

The Pumping Station at Love Grove has a history of its own. The first was erected, as already stated, in 1867 by Mr. Russel Aitkin and contained two centrifugal pumps and a chain pump. In 1869 the flow of sewage was considerably increased and in 1870 two new chain pumps were erected and one of the old centrifugals removed. In 1872, a further alteration was made, the other old centrifugal pump being removed and a new direct acting centrifugal pump put in its place. The four pumps, namely three chain pumps and one centrifugal, were together capable of lifting 20½ million gallons per diem, though not more than 8 million gallons per day found its way to the pumping station. From time to time the pumps gave trouble, and finally it was decided to erect a new Pumping Station and plant, which was included as a part of Mr. Walton's scheme sanctioned by the Corporation in 1878. The new station was completed in 1884 at a cost of a lakh of rupees, and four engines and pumps were erected therein at a further cost of a lakh and three-quarters. These engines and pumps worked until 1890, when they were condemned by Mr. Baldwin Latham as being extremely inefficient and thoroughly worn-out. A new engine-house was then constructed near the old one, and four Worthington direct-acting triple-expansion engines and pumps made by Messrs. James Simpson & Co., London, capable

of lifting 15 million gallons each per diem, together with four Babcock and Wilcox boilers, were erected at a cost of four lakhs of rupees.

These commenced to work in 1893, and are still doing their work most efficiently.

It has already been stated that brick and pipe sewers were laid in Kamatipura by Mr. Russel Aitkin, and in 1870 the district was declared by Mr. Thwaites, who succeeded Mr. Aitkin as Engineer, as one of the best-drained districts. In 1877, however, the attention of the Corporation was directed to the insanitary state of the district, and Mr. Walton was asked to report on it. Mr. Walton reported in 1880 that the system of drainage in Kamatipura was a complete failure, the joints of the pipe sewers were made of clay, storm-water and sewage were discharged into the same channels, and the brick sewers were directly connected with the old unventilated Umerkhadi sewer. He submitted a scheme for the re-sewerage of Kamatipura, which provided for the re-laying of the pipe sewers and connecting them with the new main sewer at the junction of Grant Road and Falkland Road by means of a new 2 feet 6 inches by 3 feet 9 inches branch ovoid sewer. It also provided for the exclusion of all storm-water from the sewers. The scheme was approved and sanctioned at a cost of a lakh and a half of rupees, and the works were completed in 1883.

In the same year a branch ovoid sewer, 2 feet 6 inches by 3 feet 9 inches, was constructed along Clerk Road from the main sewer to Jacob Circle at a cost of Rs. 30,000, which was in the next two years extended to opposite the Victoria Gardens at a further cost of Rs. 33,000.

In 1885 the Queen's Road sewer, which runs from opposite the B. B. & C. I. Railway Marine Lines Station and joins the main sewer at Khetwadi 10th Lane, was completed at a cost of a lakh and a half of rupees. This sewer intercepted all the sewage which was being discharged into Back Bay.

Other drainage works were also at this time pushed on rapidly, the Ripon Road ovoid sewer, 2 feet 6 inches by 3 feet 9 inches, having been completed in 1886 at a cost of Rs. 60,000; the Mint Road sewer, also 2 feet 6 inches by 3 feet 9 inches from the Mint to the Crawford Market, was completed in the same year at a cost of Rs. 90,000; and, in 1890, the pipe sewers in Agripada were laid at a cost of one lakh.

House connections were also pushed forward in various districts, the Corporation spending some fifteen lakhs of public money on these connections.

In 1889 complaints were received of nuisances existing in Marine Lines—a part of the City principally occupied by the Military—and the same being attributed to the new pipe sewer, Government appointed a Committee to inquire into the matter. The Sanitary Commissioner to Government, who was one of the Committee, made an adverse report on the sewerage of the City generally; considerable discussions also arose as to the suitability of the sewage outfall at Love Grove, and the Corporation on the recommendation of Sir Charles Ollivant, the then Municipal Commissioner, sought the advice of Mr. Baldwin Latham on the question of the drainage of the City, both present and future.

Mr. Latham came to Bombay in 1890, and his visit was a very successful one, and resulted in the Corporation obtaining a useful report known as the "Sanitation of

Bombay." He reported that the different sections of the main sewers were properly designed in regard to the population they were intended to serve, but that he found considerable silt in them, mostly due to the inefficiency of the pumping engines at Love Grove which he condemned as worn out. He found that the pipe sewers had been well laid, and pronounced the jointing equal to any he had seen elsewhere. He condemned the outfall at Love Grove and showed the fallacy of the float experiments of Mr. Jagannath Sadashiv and proved that an outfall at the Colaba point was the best. As, however, the main sewers had already been laid with a fall towards Love Grove, he recommended that all the sewage should first flow to Love Grove and be there pumped into a high-level gravitating sewer running from Parel to Colaba and discharged at the latter place at ebb-tide only beyond the Prongs Light House.

The Corporation sent a copy of the report to Government to ascertain if they would allow an outfall at Colaba, as recommended by Mr. Latham. The Government appointed a Commission who examined, among other witnesses, Mr. Baldwin Latham, who admitted that if, for financial or other reasons, the outfall could not be placed at Colaba, the existing outfall was the next best. The Commission reported that the cost of Mr. Latham's proposals was prohibitive, and that Love Grove was the second best site for an outfall, and the Government declined to sanction the new proposals.

In 1893, although a large amount of the island had been drained, there still remained several populated parts of the City where no drainage of a satisfactory kind existed. These districts were Colaba, Mazagon, Mala-

bar Hill, Chinchpokli, Parel, and the northern part of the Island.

Colaba was the first of these districts to engage the attention of the Municipality. The discharge of sewage at different points into the harbour created an intolerable nuisance, and loud complaints were made by the public. It could not, however, owing to the configuration of the land, be drained by gravitation only to the sewers already laid, and some sectional system had therefore to be resorted to. It was at first proposed to lift the sewage at some convenient point by direct-acting pumping, but the Municipality failed to obtain any suitable site for a pumping station. Both the Port Trust and the Government, who are large land-owners in the district, declined to give land for the purpose. After great discussion, it was ultimately decided in 1893 to drain the district on the Shone System. The works were designed and carried out by the late Mr. J. W. Smith at a cost of eight lakhs of rupees. They provide for a prospective population of 28,000 people, the present population being about 18,000.

The district is divided into five blocks, each having an ejector station as shown in Plate 54.

Nos. 1, 2 and 3 ejector stations have each two ejectors of 500 gallons capacity each, No. 4 ejector station, two ejectors of 300 gallons capacity each, and No. 5 station, two ejectors of 100 gallons capacity each. One ejector is sufficient to cope with the sewage in each block, the other being held in reserve. The stations are built of bricks set in cement mortar, plastered on both sides with cement.

The compressed air is supplied to the ejectors from an Air Compressor Station erected in a convenient position near the Arthur Basin. In this are placed three compound non-condensing engines, each of 40 indicated horse-power, with two marine boilers of the type known as the "Dry Back Tubular." Two engines and one boiler are sufficient to deal with the maximum requirements of the whole district, the third engine and the other boiler being a stand-by. Each of the engines is designed to deliver 450 cubic feet of free air per minute, compressed to 22 lbs. above atmospheric pressure.

The compressed air is delivered into an air-receiver, placed outside the engine-house, having a capacity of 800 cubic feet. The air main is coupled up to the receiver, and supplies air to each of the stations by means of suitable branch pipes.

A sealed sewage main is laid from No. 3 ejector station to the Wellington Fountain at the north end of the Colaba district, with branches from Nos. 1 and 2 ejector stations, and discharges into a long chamber near the Fountain. From this chamber the sewage flows into the gravitation pipe sewers. The use of the chamber is to receive the contents of the sealed sewage main, should they be required to be suddenly blown out in the case of an obstruction taking place in the main. No. 4 ejector station discharges its sewage through a short length of sealed sewage main into the head of a sewer gravitating to No. 3 station, where it is all re-lifted, while No. 5 discharges also through a short length of sealed sewage main into the sewer gravitating to No. 4, where the sewage is re-lifted and sent to No. 3, where it is again re-lifted. The double

lifting of the sewage of No. 4 sub-district and the treble lifting of that of No. 5 has been adopted as being economical, for the reason that to force the sewage of these sub-districts, which is comparatively small in quantity, through a rising main from one end of Colaba to the other, would require compressed air at a much higher pressure than necessary for the other three stations, where the greater part of the sewage of the district gravitates.

The drainage of this district was completed in 1895, and house-connections were immediately taken in hand, not on this occasion at the cost of the Corporation, but of the owners themselves, and completed in the following year.

The Shone System at Colaba gave such satisfaction that it was decided in 1897 to extend the System to other districts, *viz.*, Mazagon, Parel, Chinchpokli, the Old Race Course and Malabar Hill.

It was considered more economical to provide at one Station the air compressing machinery required for all these districts than to construct separate installations for each of them. The Corporation therefore sanctioned in 1897 the construction of an Air Compressor Station at Love Grove to the North of the Pumping Station, and the erection of the air compressing machinery, and the laying of air mains, capable of dealing with the sewage of all the above districts, at a cost of 8 lakhs.

Simultaneously with this work, the Sewerage of the Mazagaon District was also taken in hand. Here two ejector stations have been constructed at the positions shown in Plate 55, one containing two ejectors of 1,200 gallons each, and the other two of 250 gallons each. In

this district the ejector stations have been built of cast-iron tubbing, owing to the presence of much subsoil water. The work was completed in 1899 at a cost of 3½ lakhs.

In 1900-1901 a further extension of the Shone System was sanctioned for the districts of Chinchpokli and Parel. These works have been pushed on with vigour, and are now drawing towards completion. There are two ejector stations in the former district, and three in the latter. Plate 56 shows the positions of the five ejector stations, and the pipe sewers, air mains and sealed sewage mains.

Ejector station No. 1 in the Chinchpokli District is built of brick-work in cement and contains two ejectors of 1,000 gallons each, while that in No. 2 is of cast-iron tubbing, containing two ejectors of 1,200 gallons each. The ejector stations Nos. 1 & 3 in the Parel District are brick chambers, while No. 2 is of cast-iron tubbing. No. 1 station contains two ejectors of 700 gallons capacity each, No. 2 contains two ejectors of 1,000 gallons capacity each, and No. 3 contains two ejectors of 600 gallons capacity each. The compressed air is supplied to these stations from the Air Compressor Station at Love Grove. All the sewage is discharged into existing gravitation sewers and flows to the Pumping Station at Love Grove. The cost of sewering these two districts has been about 9 lakhs.

There now remains only the drainage of Malabar Hill, the Elphinstone Estate, the Agripada Estate, and the North of the Island, to be undertaken.

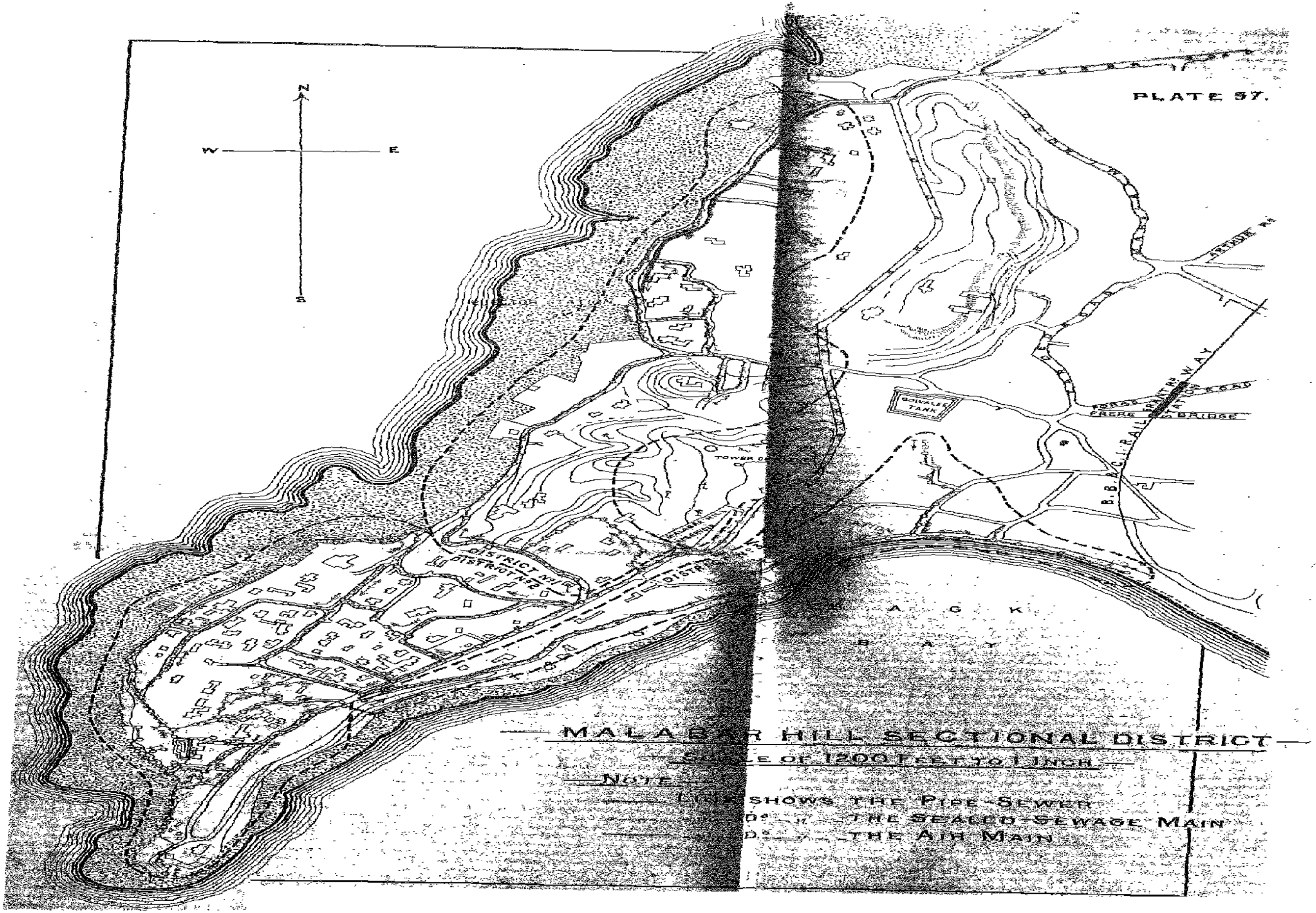
The Agripada and Elphinstone Estates are to be drained on the Shone System, the compressed air being

supplied from the present station at Love Grove. Each district will have two ejector stations, with duplicate ejectors in each.

As regards Malabar Hill, the proposals now before the Corporation are to deal with half the sewage on a biological system, to drain about a third of the district to the north on the Shone System, and the remainder near Chaupati by low-level sewers and a small pumping plant.

Plate 57 shows the three divisions of the district and the drainage arrangements in each sub-district. No. 1 is that which is to be drained on the biological system, the purified sewage being discharged at once into the sea. The prospective population is taken at 8,000 and the daily flow of sewage at 300,000 gallons. The sewage is to first flow into a closed septic tank, having a capacity of one day's flow of sewage. This tank will be 160 feet by 50 feet by 6 feet, and so constructed that it can be cleaned in sections. Connected with the tank will be duplicate catch-pits and screening chambers to arrest such materials as rags, road detritus, and other mineral matter in the sewage. The effluent from the septic tank will flow on to a series of 6 contact beds, for its final purification, each of the beds being 110 feet by 32 feet by 3 feet. These beds will be filled with 1 inch cube metal. Besides further purifying the septic tank effluent, the contact beds will serve also as a storage tank when the tide is above the level of the beds. The installation is to be built on the Western Foreshore with a wall protecting it from heavy seas. It is proposed to utilise the gas from the septic tank for lighting the installation at night and also for burning the screenings from the sewage.

PLATE 37.


N
W
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GOWALEE TANK
TOWER OF
DISTRICT No. 1
DISTRICT No. 2
B
A
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K
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Y
B.B.&C.I. RAILWAY
FRERE BRIDGE
ROAD
MALABAR HILL SECTIONAL DISTRICT
SCALE OF 1200 FEET TO 1 INCH
NOTE
LINE SHOWS THE PIPE-SEWER
Do. " THE SEALED-SEWAGE MAIN
Do. " THE AIR MAIN

No. 2 sub-district is to be drained on the Shone System, an ejector station containing two ejectors of 250 gallons capacity each being placed in Warden Road near Scandal Point. The compressed air will be supplied from Love Grove and the sewage lifted and discharged into an existing gravitation pipe-sewer, a few hundred feet to the north of the ejector station.

The sewers in No. 3 sub-district will gravitate to a point on the Chaupati Estate, where the sewage will be lifted by means of an oil engine and pumps into a gravitation sewer.

The total cost of drainage of the three sub-districts is estimated to be :—

Sub-district No. 1	..................Rs.	3,19,439
Do. ,, 2	.... ,,	1,99,635
Do. ,, 3	.... ,,	1,20,874
	Total...Rs.	6,39,948

It may be noted that the cost of sewering the whole of the district on the Shone System, as originally intended, was estimated to cost Rs. 7,71,190 or Rs. 1,31,242 more than the above estimate.

With regard to the drainage of the north of the Island, the scheme proposed is to dispose of the sewage of three villages, Wadala, Gowari and Khara, lying to the east of the ridge, by biological treatment and a sewage farm. It is impossible, owing to the position of these villages to drain them to the Love Grove Pumping Station without some scheme of local pumping, and the initial and annual recurring expenses involved in such a scheme would be out of all proportion to the importance of the villages.

It is, therefore, proposed to drain them by open drains and pipe sewers to a sewage farm after passing the sewage through an Open Septic Tank. Open drains have been adopted in part of the scheme, owing to the difficulty of obtaining self cleansing gradients for closed sewers. At the junction of open drains with pipe sewers, storm-water over-flows will be provided, which will pass all domestic sewage in the fair weather from the open drain to the sewer, but, in the rains, will discharge rain water and diluted sewage into storm-water drains. Sewage should not, however, be allowed to pass into storm-water drains or ditches, unless diluted with at least 6 times its volume of rain water.

The population is taken at 4,000, 20 gallons of sewage per head per diem being provided for.

The buildings in these villages are for the most part one storied and can be more aptly described as huts than houses; it is, therefore, proposed to avoid house connections as far as possible, and provide public latrines and washing places at different points.

It is further proposed to acquire for the farm 16 acres of land to the east of the Matunga Leper Asylum. The Septic Tank will be of sufficient capacity to hold three-quarters of one day's dry weather flow, an l the sewage will be passed through a screening chamber and a catch-pit before entering the Tank. The effluent will be conveyed on to the farm by suitable carriers.

The crops to be grown on the farm will be Guinea grass, kurby, jowar, and different kinds of vegetables. Quarters will be provided at the farm for the supervising staff and the malis.

The cost of these proposals is estimated at Rs. 2,12,426.

This scheme should not only afford a satisfactory solution of the problem of the drainage of such villages, but should also be financially a paying one. If this expectation is realised, other similar out-lying villages in the north of the City will probably be similarly dealt with.

Another proposed drainage scheme is for the village of Dharavi, situated in the extreme north of the Island. Dharavi is principally inhabited by employès of the various tanneries situated in the village, and by a colony of fishermen. There are some fifty tanneries and the daily amount of sewage from these is 330,000 gallons. The population is about 6,000 and with 20 gallons of water per head per diem, the amount of domestic sewage will be 120,000 gallons per day. It is not possible to drain the village on a gravitation system to Love Grove, and sewage containing so large a proportion of tannery waste cannot be treated biologically. It has, therefore, been decided to discharge the sewage on the ebb-tide into Mahim Bay, after passing it first through precipitation tanks, and, if necessary, chemically treating it with alumino-ferric. Chemical treatment will not be tried in the first instance but will be adopted, should ample screening and precipitation prove inefficient. There will be three outfalls, to which the sewage will be conveyed for the most part by open drains, the configuration of the district making it impossible to drain the whole village by gravitation to one outfall; and even with three outfalls the levels would not allow of closed drains being wholly laid.

At each outfall a precipitation tank, capable of holding three hours' dry weather flow, will be constructed and the sewage will be screened through sloping screens in its passage into the precipitation tank. In order not to foul the foreshore of Mahim Bay, the discharge of sewage will be only on the ebb-tide and storage tanks will therefore be constructed in connection with the precipitation tanks. The storage tank at each outfall will be capable of containing 75% of the estimated dry weather flow of sewage discharging at that outfall. Plate 58 shows the arrangement at one of the outfalls.

As in the case of the villages of Wadala, Gowari and Khara, so also in this case house connections will be avoided, public latrines and washing places being constructed at certain places.

The total cost of the scheme is estimated at Rupees 1,75,000.

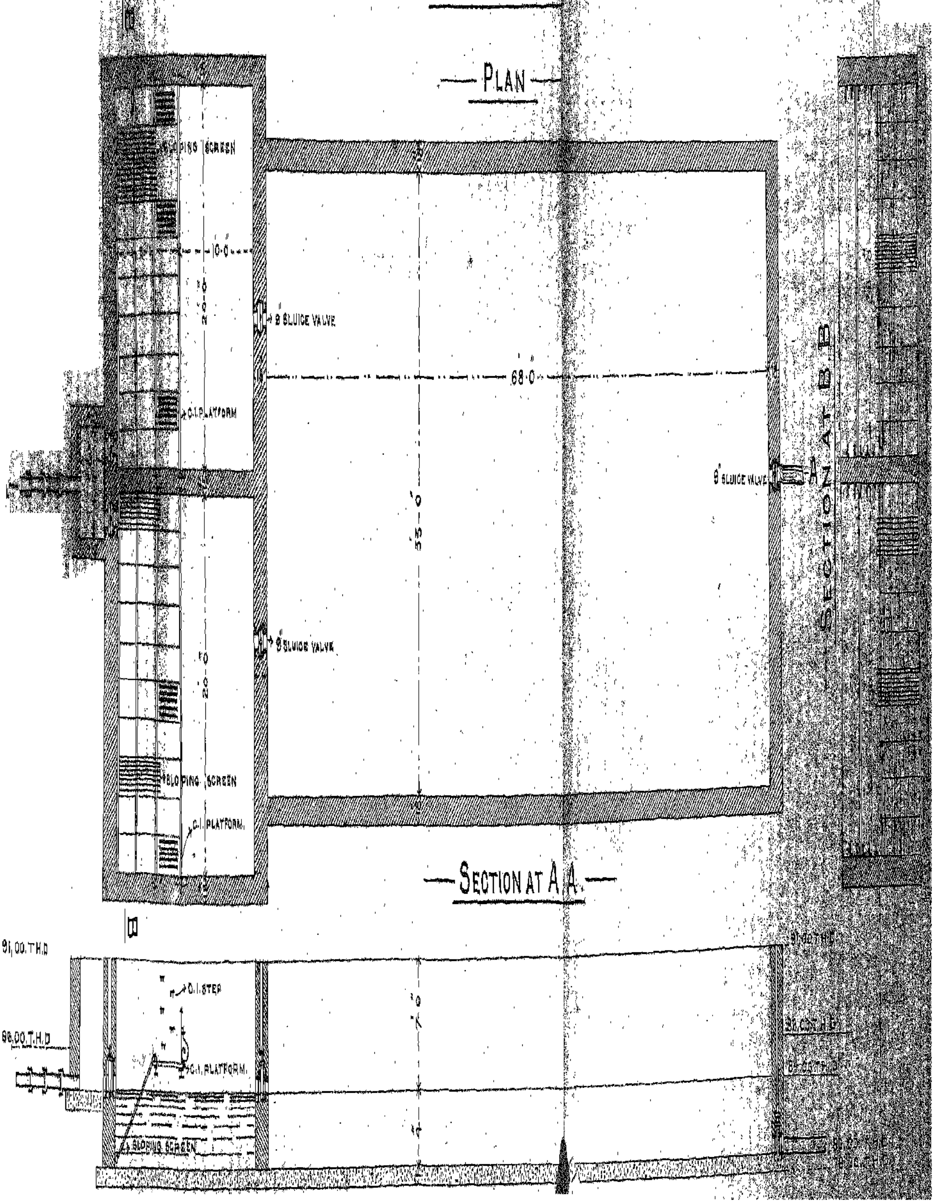
Plate 59 shows the parts of the Island drained on the gravitation system and those on the Shone System.

Nothing has yet been finally decided as regards the drainage of the other parts of the north of the Island, but the consideration of this must, of necessity, force itself on the authorities in the next few years, as the City is gradually extending in that direction.

In the Autumn of 1899 the late Mr. W. Santo Crimp, at the request of the Corporation, visited Bombay to advise on the various drainage questions, particularly that of the disposal of the surface-water of the City and that of the discharge of sewers at the Love Grove outfall. For a long time loud complaints had been made by the public regarding

— STORAGE & PRECIPITATING TANKS AT AN OUTFALL AT DHARAVI —

— Scale 10 Feet to 1 inch —



the sewage discharged at the Love Grove outfall, the smell being perceptible, particularly at the time of the ebb-tide, all along the western foreshore of the Malabar Hill. The history of the outfall has been touched upon in the early part of this Chapter, where it has been pointed out that a small clerical error has been the cause of years of trouble and nuisance to a part of the Island which should have been, in regard to its healthy condition, the most desirable residential quarter of the City.

Mr. Santo Crimp caused a series of float observations to be taken at Love Grove, the results of which are very interesting and are shewn in Plate 60. They show without doubt that the sewage discharged on an ebb-tide flows on the surface of the sea and is carried by the tide well down and towards the coast in the direction of the Malabar Point. On the other hand a flowing tide took the floats well out into the sea and up the coast.

The following remedies have been proposed by Mr. Santo Crimp to overcome the nuisance during the ebb-tides :—

(1) The extension of the present outfall into deeper waters ;

(2) Treating the sewage discharged during the first four hours of the ebb-tide with electrolyzed sea-water ;

(3) Treating the sewage discharged during the first four hours of the ebb-tide with Permanganate of Potash ;

(4) An extension of the outfall sewer to Worli Point, discharging at that point all the sewage during ebb-tide, and at the Love Grove outfall during the flowing tide.

The first remedy proposed is now impracticable, and of the remainder, the fourth is probably the most economical and satisfactory.

It will be seen from this description that the drainage of Bombay presents an exceptional variety of different systems, and accordingly there can be few cities, if any, in India of greater interest or higher educational value to students of sanitation. The ignorance and indifference of former times in sanitary matters are now happily well nigh things of the past and in Bombay the leading citizens have for many years taken a keen, helpful and most intelligent interest in sanitation and kindred matters. The last six years of plague have taught many lessons, not the least valuable and far reaching of which is the appreciation of cleanliness and sanitation, which seems to be now becoming general even among the humblest.

CHAPTER VIII.

Glossary of Terms.—In all works on Engineering, and more particularly in these days of specialized branches of Engineering, many technical terms and names are used which are not to be found in any dictionary. It is therefore deemed desirable, for the information more particularly of students interested in the special subjects with which this work deals, to give an interpretation of such terms. Some are peculiar to certain districts in India, an example being *Nahani*, a washing place, another name for which is *Mori*, a word which is to a greater extent used outside the Bombay Presidency than within it. Certain it is that the meaning of many of the names used, though familiar to Sanitary Engineers in the East, would be quite unknown to Engineers practising in Europe, and therefore the Author hopes that this glossary may be useful, not only to students interested in Sanitary Engineering, but even to Engineers. If some of the terms seem to be too simple and well-known to require definition, it should be remembered that English is a foreign language to many Eastern students, and it is to them that this work is in part addressed.

ADJUTAGE ... ... Helper. The name given to a lip on the top of the inner leg of an automatic siphon, which helps the siphon to start flushing by allowing the water to fall over without touching the side of the leg.

AERATION ... ... Impregnation with air or gas.

AEROBIC ... ... "Living in contact with air." The term is applied to certain micro-organisms which live preferably in the presence of atmospheric oxygen and which oxidize the ammonia in sewage into nitrites and nitrates. Aerobes are divided into facultative and obligate aerobes. The former can live in the absence of oxygen, the latter are unable to do so.

ALLUVIAL ... ... The term applied to the soil and miscellaneous substances collected and deposited by the action of water.

ANAEROBIC ... ... "Living without air." The term is applied to certain micro-organisms which live preferably without air, and which reduce the organic matter in sewage, thus preparing it for treatment by aerobic bacteria.

ANNULAR ... ... Having the form of a ring, pertaining to a ring.

ANTI-SIPHONAGE PIPE. The term given to a small pipe which supplies air to siphons and traps, and prevents their being untrapped by a partial vacuum being formed through a sudden rush of water falling in a pipe to which the siphon or trap is connected.

ARGILLACEOUS STONE The class of stone in which alumina or clay is the characteristic constituent, such as slate and shale.

ARRIS ... ... Edge: a term often applied to bricks; for instance, it should be specified that bricks should have good sharp arrises, *i.e.*, sharp edges.

AUTOMATIC ... ... Having the power of self motion, that which is self moving; self acting.

BACTERIA	Bacteria is a generic term applied to a number of minute unicellular organisms belonging to the vegetable kingdom which multiply by fission only. The scientific term including all members of this group is Schizo mycetes or Fission-fungi. In this book the word bacteria is used loosely to include micro-cocci and other members of this family.
BAFFLE WALL ...	A wall built in a tank or channel to check the velocity of the flow.
BASALTIC	A term applied to any substance derived from basalt, a rock of volcanic origin.
BIOLOGICAL TANK..	A receptacle for liquid so constructed as to furnish to the micro-organisms contained therein the conditions most favourable to the efficient performance of their work in the direction of sewage purification.
BOARD OF CONSERVANCY.	The body of men appointed to carry out measures for the preservation of health and cleanliness within a certain district.
BONING ROD... ...	A T.-shaped piece of timber of a certain length, used in checking the levels of excavations or pipes.
BRIQUETTE	A name derived from the French "Brique," a brick, and applied in Engineering to a small brick, made generally for testing purposes, as in cement testing.
BY-PASS	An auxiliary passage by the side of a conduit or pipe.
CALCAREOUS STONE.	The class of stone in which carbonate of lime predominates, such as marbles, lime stones, etc.
CAMBER	A slight convexity or arching given to a road cross-wise to allow the surface water to drain off readily.

CAPACITY ... ... The quantity which a vessel is capable of containing or a channel of discharging. In case of sewers, the capacity is equal to the area of the sewer multiplied by the velocity.

CATCH-PIT ... ... A chamber built below the level of the invert of a sewer in which the velocity of the flow is reduced so as to collect such heavy deposit as may be in the sewage.

CENTRING ... ... The framing of timber by which an arch is supported during its erection.

CESSPOOL ... ... A receptacle for sewage, a chamber built near a dwelling to receive and temporarily hold the sewage of the house until it can be removed.

CHAIN-PUMP ... ... A pump consisting in one of its simplest forms of an endless chain equipped with a series of disks, passing downwards into the water, and returning upwards through a tube.

CLINKER... ... ... The incombustible portion of coal partially fused, which forms in grates and furnaces.

COMBINED SYSTEM. The name given to the system of sewerage, in which the conduits are constructed for the double purpose of receiving both sewage and surface water.

CONFIGURATION .. The external aspect or contour of the land or district.

DASH-POT ... ... An apparatus for preventing the too sudden movement of parts. It usually consists of a small cylinder filled with oil and fitted with a piston through which a minute hole is drilled. The piston rod is attached to the part to be controlled.

DATUM ... ... Some fact or quantity granted or known from which other facts or quantities are calculated, *e.g.*, a certain step at the Town Hall, Bombay, is assumed to be 100 feet above an imaginary plane for the purpose of calculating other levels in the City.

DECANTATION ... The act of pouring from one vessel to another so as to separate one part of the liquid from another or to separate the liquid itself with matter in suspension from matter precipitated in it, such as clay from sand, by putting the mixture into the water in a vessel, stirring it and then pouring it off into another vessel; the liquid thus poured off carrying away the lighter particles of clay.

DEODORIZE ... ... To deprive anything of the fœtid odour resulting from impurities.

"DHAPA" ... ... A slab stone used for covering or spanning a masonry drain.

"DHOBI GHAT" ... A public place used for washing clothes and sometimes belonging to and under the supervision of the local authority.

DIAPHRAGM ... ... *Vide* "Parda."

DISK-VALVE ... ... A circular sliding iron door used for closing a pipe sewer.

DOMESTIC SEWAGE. The sewage derived from the habitations of man and beast as opposed to that derived from factories.

DOUBLE DISK ... Two round blocks made principally of wood, fixed 12 inches apart and connected by bolts. An arrangement for passing through pipe sewers to cleanse the same.

DROP PIPE ... ... A vertical pipe joining two sewers at different levels in a manhole.

DRY SYSTEM LATRINE. A privy where fœcal matter and sullage are temporarily collected and afterwards removed by hand.

EJECTOR ... ... The name given by Mr. Shone to a spherically ended container, which receives and ejects by compressed air the sewage.

EXTRADOS ... ... The name given to the outside curve of an arch.

FAUCET ... ... That end of a pipe which is enlarged to receive the spigot end of another pipe to make a joint.

FILLET ... ... See Splayed.

FLAP VALVE ... ... A broad shutter made of wood or metal and hung over the face of a sewer and falling by its own weight and completely closing the sewer.

FLUSHING DOOR ... A flap which is let down by a hinge and closed over the face of a sewer or conduit to detain the sewage or liquid behind it, and which, when opened, allows the liquid to flow away with a rush.

FŒCES ... ... The solid matter excreted by human beings; night-soil.

FOOT RESTS ... ... Raised surfaces in latrines or urinals to place the feet on, thus marking the exact place for standing or squatting upon.

FORESHORE ... ... The sloping part of the sea shore between high and low tides.

"GAMEL" ... ... An iron pan for carrying materials generally of a semi-liquid nature, such as mortar.

GASKET ... ... A thin twisted or plaited rope of hemp put first into the joint of pipes to prevent the cementing material from passing through into the pipes.

"GHANI" ... ... An Indian term for a mill used in grinding mortar, the motive power for which being usually bullocks or buffaloes.

GRADIENT ... ... The name given in Sanitary Engineering to the inclination or slope of a pipe or conduit. The vertical fall divided by the horizontal distance.

GRAVITATION ... ... The act of tending to a centre of attraction, as when water flows from a higher to a lower level.

GROUT ... ... Cement mixed with water to the consistency of cream and used to fill up joints and holes in masonry.

"GULLY" OR "HOUSE-GULLY." A name given to a narrow open passage between houses, also called a sweeper's passage, as it affords access to sweepers and halalkhores to the latrines or privies of the house.

"HALALKHORES".. The caste of people employed to remove by hand, fœces, &c., from privies and dry system latrines.

HAUNCHES ... ... A term applied to the middle part between the crown and springing of an arch. In a semi-circular drain the filling of the part between the side wall and the circular part of the drain.

HIGH-LANDS ... ... The name given to lands above high-water spring tides.

HUMID ... ... Moist, damp.

HUMOUS OR HUMUS Vegetable mould; or the matter deposited in a biological tank or filter.

HYDRAULIC ... ... A term relating to the conveyance of water through pipes, or channels.

HYDRAULIC LIME... The term applied to lime which will set in the presence of water.

HYDRAULIC MEAN DEPTH. The quotient obtained by dividing the area of the cross section occupied by the liquid by the wetted perimeter.

INLET ... ... The term applied to the higher or upper end of a pipe or conduit, or that end which discharges into a manhole, tank, etc.

INSPECTION CHAMBER. A masonry chamber built on a house drain and covered with a removable cover for the inspection of the drain.

INTERCEPTING TRAP A trap or siphon placed on a house drain between the sewer and the house to intercept and prevent gas from the former passing up the drain or into the house.

INTRADOS ... ... The name given to the inner curve of an arch.

INVERT ... ... The name given to the lowest portion of a sewer, pipe or drain.

"JAGGORY" ... ... Coarse brown (or almost black) sugar made from the juice of sugar-cane or the sap of various palms, often seen in the form of small round cakes.

"JOWAR" ... ... Hindustani name for millet.

JUMP-WEIR ... ... A name given to an arrangement, made at the street end of a house-gully, which permits of a small flow of sullage from the gully to fall into a trap in connection with the house drain, but allows of a greater flow of surface water to pass over and discharge into a drain set apart for the purpose.

"KANKAR" ... ... A class of hydraulic lime-stone, composed mostly of carbonate of lime, but also containing an admixture of clay and sand.

"KHANKI" ... ... A stone fair-dressed on the face and rough-dressed on the other sides, fixed at the edge of a road bordering on an open drain, or used as facing in a stone building.

"KURBI" ... ... Hindustani name for Indian corn or maize.

"LAKH" ... ... One hundred thousand.

LATRINE... ... ... A privy, or a place set apart for natural purposes. It may be either on the dry or water carriage system.

LIFTING GEAR ... An arrangement used for the raising or lowering of flushing doors by means of chains.

LIQUEFACTION ... The reducing of solid organic matter to a liquid state by the action of bacteria.

LOAM ... ... A species of earth consisting chiefly of rich vegetable mould, a light earth or marl.

LOW-LANDS ... ... The term applied to those lands which are situated below high-water spring tides.

MACADAMIZE ... ... (From Macadam, the Inventor). To cover a road with small broken stones, which, when consolidated, form a firm surface.

"MALI"... ... ... The Hindustani name for a gardener.

MANHOLE ... ... A masonry chamber built on a sewer or drain, through which it is possible to enter and have access to the sewer or drain for cleaning and inspection purposes.

MICRO-ORGANISMS.. In this book the word may be taken to mean bacteria (see Bacteria).

"MORI"... ... ... A place prepared with masonry and set apart or used for washing or bathing purposes, either inside or outside a house.

"MURAM" ... ... A local name given to the stratum of disintegrated rock lying between the clay and basaltic rock.

"NAHANI" . ... See "Mori."

NIGHT-SOIL ... ... The solid matter excreted by human beings; fœces.

"NULLAH" ... ... The Hindustani name for a water-course, a rivulet.

OUTFALL... ... ... The name given to the locality or localities where the sewage or surface water is finally disposed of.

OUTLET ... ... The lower end of a sewer or conduit or the end through which the sewage is discharged from a manhole, tank, etc.

OVOID ... ... A term used to describe sewers built in the shape of an egg.

OXIDATION ... .. A term used in sewage purification to denote the final change which takes place in destroying organic matter, the addition of oxygen to the effluent by the admission of air to the latter.

"PARDA" ... ... The name given to a stone slab fixed in the sides of a surface water gully so as to dip into the water and form a trap.

PATHOGENIC ... ... The name given to denote a class of organisms which, when introduced into the body, give rise to diseases (Pathogenic disease producing).

PENSTOCK ... ... A gate usually made of iron and built into a sewer or facing a drain, so that it can be raised or lowered at will controlling the discharge of sewage or water.

PERENNIAL ... ... Perpetual, running throughout the year.

PLASTIC ... ... A substance capable of being moulded, used in patent jointed pipes to prevent the cement running into the pipe.

PLINTH ... ... The masonry foundation of a house up to the level of the ground floor.

PLUMB ... ... Vertical or straight.

PLUMB-BOB ... ... A weight attached to a string to test the uprightness or verticality of any object.

PNEUMATIC SEWER-NET. A term used in the Liernur method of drainage, to mean a series or net-work of pipes.

PNEUMATIC SYSTEM. The system in which vacuum or compressed air is the motive power employed for lifting sewage.

POLING BOARDS ... Boards intended to support the sides of a trench and placed behind the walings.

PRECIPITATION ... The process by which a substance held in suspension in a liquid is made to separate from another or others and fall to the bottom.

PRIVY ... ... A latrine on the dry system.

PUBLIC CONVENIENCES. Places set apart for the accommodation of the public such as latrines, urinals, washing places, dhobi ghats, cab stands.

PUDDLE ... ... Clay worked up by being mixed with water to a plastic or sticking condition.

PUMICE STONE ... A porous stony substance of volcanic origin.

PUNNED ... ... Rammed, packed tight by pounding.

RENDERED ... ... Made smooth, plastered in cement.

ROAD DETRITUS ... The term used to denote the small particles of disintegrated stone, etc., worn off from the surface of the roads by traffic.

RUBBLE ... ... Rough irregular stones used in coarse masonry or to fill up between the facing courses of masonry.

SCRAPER, or SHIELD An appliance used in cleaning an ovoid sewer and made in the shape of the sewer with a portion of the bottom or the top cut off. When inserted in the sewer it heads up the sewage by contracting the area of the flow, which is consequently accelerated and facilitates cleaning by softening the deposit.

SCREEN ... ... A riddle or sieve used to separate fine matter from coarse, either solid or liquid.

SCUM-BOARD ... ... A board placed across, and descending six to eighteen inches below the surface of the fluid in a tank, to check the flow and thereby arrest the floating matter.

SEAL ... ... The depth of contained water in a trap which prevents the free passage of air or gas through it.

SECTIONAL SYSTEM. The name given to the system of sewerage, in which a district is divided into sections, each of which has sewers gravitating to one point within it.

SEPARATE SYSTEM... The name given to a system of sewerage, in which there are different conduits for storm-water and sewage.

SEPTIC ... ... A term denoting the promotion of putrefaction, or the breaking up and liquifying of organic matter by bacteria and the liberating of various gases.

SET STONE ... ... A medium dressed stone 6 inches by 9 inches by 1 foot 6 inches deep, used for paving purpose in places liable to heavy traffic.

SEWER ... ... A main conduit for the conveyance of sewage.

SEWAGE ... ... The filthy liquid containing excrementitious and other matters from houses and towns which passes through drains.

SHORED ... ... Propped or supported by timber.

SIGHT RAILS... ... Rails about 4 inches by 2 inches fixed across an excavation on wooden posts with their tops at a certain height above the intended level of the bed of the sewer. A line of sight along the tops of the rails so fixed would be parallel to the gradient of the sewer.

SILICIOUS STONE ... A class of stone in which silica or sand is a characteristic constituent, such as granite, trap, basalt, etc.

SILT... ... ... A term given to the deposit of solid matter found in sewers and drains.

SIPHON ... ... A bent tube whose legs are of unequal length, used for drawing liquid out of a vessel, the shorter leg being inserted in the liquid and the larger hanging down outside ; when the air is sucked from the tube the pressure of the atmosphere causes the liquid to rise in it and flow over.

SIPHONAGE ... ... The action or operation of a siphon.

SLUDGE ... . Soft mud, the term applied to the deposit in biological tanks and filters.

SLUICE ... ... A contrivance for excluding or admitting the inflow of a body of water.

SOCKET ... ... The opening at the end of a pipe generally enlarged, into which is inserted the end of another pipe to make a joint ; see Spigot.

SOIL PAN ... .. A receptacle fixed in a latrine or a water-closet, to receive fœcal matter.

Soil Pipe ... ... A vertical pipe fixed against a wall to take the discharge from water closets.

Specific Gravity.. The weight of the bulk of any substance compared with that of the same bulk of water.

Spigot ... ... The end of a pipe which is inserted into the enlarged end of another pipe to make a joint.

Splayed Fillet ... A narrow band of cement used to complete the joint of a pipe and having a sloped surface.

Stratum... ... ... A layer or bed of stone or earth. Strata (the plural), several such layers superposed above each other.

Sterilization ... By the expression sterilization of any substance is meant destruction or removal of all germs and their spores contained in or on such substance. The former is usually effected by the application of heat or germicidal disinfectants and the latter, in the case of liquids, by filtration through a Pasteur or Berkfeldt filter, which removes all germs and spores from the liquid.

Street Connection. That part of the house drain which lies between the street sewer and the boundary of the house.

Stop Tap ... ... The name given to a cock used in connection with an Adam's time-siphon.

Subsoil ... ... The beds or strata which lie below the surface soil.

Suburban ... ... Relating to suburb, or a district on the out-skirts of a city or a town.

Sullage.. ... ... The liquid and other matters discharged from bath, cook-room, etc., and not containing excrement.

SUMP ... ... A reservoir or pit below a pump, the lowest point.

"SURKI" ... ... A fine powder made by crushing burnt brick.

TENSILE STRAIN ... The power to resist straining, or stretching applied along the length of any material.

TIDAL-FLAP ... ... A door attached to a sewer at a manhole, by which the sewage may be retained in the sewer for flushing purposes (properly a gate used to exclude tidal water).

TRAPPED ... ... So formed as to hold a depth of water sufficient to prevent the free passage of air or gas.

TRADE SEWAGE ... Sewage derived from factories containing chemical matter.

TUBBING... ... ... A water-tight cast-iron chamber constructed underground to contain an ejector or ejectors.

TUFA ... ... A light porous rock of volcanic origin.

URBAN ... ... That part of a large city or town which has been fully built upon.

VELOCITY ... ... The rate of movement or flow, the distance traversed in a given time; usually expressed in feet per second or per minute.

VENT PIPE ... ... The pipe connected with a sewer or drain to maintain an equilibrium of pressure between the outside air and the inside air of a sewer and to allow of the discharge of the sewer air into the open air, or the admittance of outside air into the sewers.

VENTILATE ... ... To create a current of fresh air through a sewer or drain so as to cleanse it of foul air.

VOUSSOIRS ... ... Wedge-shaped stones or blocks of concrete used in constructing an arch.

WALING	A piece of timber placed horizontally to support the sides of a trench.
WASH-DOWN CLOSET.	A latrine on the water carriage system, the soil pan of which discharges downward into the trap.
WASH-OUT CLOSET	A latrine on the water carriage system, the soil pan of which discharges horizontally into the trap.
WASTE WATER PIPE.	A vertical pipe placed against a building for the discharge of sullage.
WATER CARRIAGE LATRINE.	A privy, the fœces from which are carried to the sewers by water.
WATER CLOSET ...	A latrine on the water carriage system.
WATER GULLY ...	A trapped chamber through which the surface water from the road flows into an underground drain.
WATER TABLES ...	Flat dressed stones fixed at the sides of a road over which the surface water from the road flows to the water gully or drain.
WETTED PERIMETER.	The length (measured at right angles to the flow) of such parts of the sides and bottom of a conduit or channel as are in contact with the liquid.
WINDSAIL	A tube or funnel of canvas used to convey air into sewers or drains.

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